Testing of Three Factory-Built Chimneys

Prepared for:

The Research Division
Policy Development and Research Sector
Canada Mortgage and Housing Corporation

by:

ORTECH International, Mississauga

Principal Consultant: Colin A. McGugan

CHMC Project Manager: Don Fugler

December 8, 1989

D I S C L A I M E R

THIS PROJECT WAS FUNDED BY THE CANADA MORTGAGE AND HOUSING CORPORATION AND ENERGY MINES AND RESOURCES CANADA. THE VIEWS EXPRESSED ARE THE PERSONAL VIEWS OF THE AUTHORS. NEITHER THE CORPORATION NOR EMR ACCEPTS RESPONSIBILITY FOR THEM.

1.0 INTRODUCTION

As part of a study of the performance of factory-built fireplaces, Canada Mortgage and Housing Corporation (CMHC) engaged ORTECH International to carry out laboratory testing of three factory-built chimneys connected to a factory-built fireplace.

Results of previous tests were reported in ORTECH Report ESC-89-18, "Performance Requirements and Design Guidelines for Fireplaces with Closed Combustion Chambers".

In that work, tests were carried out on fireplaces using type A chimneys. Concerns have been raised regarding operation of fireplaces with air-cooled chimneys. It was felt that a fireplace with an air-cooled chimney might be more prone to draft problems than a fireplace with an insulated chimney.

2.0 DESCRIPTION OF CHIMNEYS AND FIREPLACE

Three chimneys were selected for additional testing with Fireplace E. Chimney A was an air-cooled chimney, with a 200 mm inside diameter and a 300 mm outside diameter. Cooling air was supplied through a 100 mm duct running from the base of the chimney to air intake hood on the exterior wall of the test room. Chimney B was a type A chimney, with a 200 mm inside diameter and a 250 mm outside diameter. Chimney C was a 650°C chimney, with a 200 mm inside diameter and a 300 mm outside diameter. The chimneys were tested in conjunction with a standard factory-built fireplace designed for use with the air-cooled chimney.

3.0 CHIMNEY TEST PROCEDURES

A standard factory-built fireplace designed for use with an air-cooled chimney was used for all of the chimney tests. The fireplace was installed in ORTECH's fireplace test facility shown in Figure 1. The fireplace was instrumented with thermocouples on the

inside surface of the fire chamber, and on the inlet and outlet of the circulation air plenum.

Thermocouples were installed on each of the test chimneys at a number of points. The chimneys were constructed from 0.91 m sections. Sets of thermocouples were placed 0.1 m from the base of each section, at a height of 1.2 m, and 0.1 m from the top of the chimney. Each set of thermocouples consisted of one placed in the centre of the flue, one mounted on the inside surface of the flue, and one mounted on the outside surface of the flue. Chimney A was tested as an inside chimney, installed in a flue enclosure, and as an outside chimney without an enclosure. Chimney B was tested as an inside chimney only, and chimney C was tested as an outside chimney only. For the outside installation, a 30 degree elbow of the same construction as the chimney was installed on the fireplace outlet, followed by 1.2 m of chimney to a second 30 degree elbow outside of the test room. From there, the chimney went straight up, along the outside of the test room in the outdoor air plenum. Figure 2 shows diagrams of the inside and outside installations.

4.0 RESULTS OF CHIMNEY TESTS

The air-cooled chimney had some operating characteristics which were different from the type A and 650 chimneys. In general, the outside surface temperature of the type A and 650 chimneys decreases with height, as shown in Figure 3. With the air-cooled chimney, there was an initial increase in outside temperature with height, as shown in Figure 4. This increase was partially attributed to an increase in the temperature of the cooling air inside the chimney as it travelled up through the chimney.

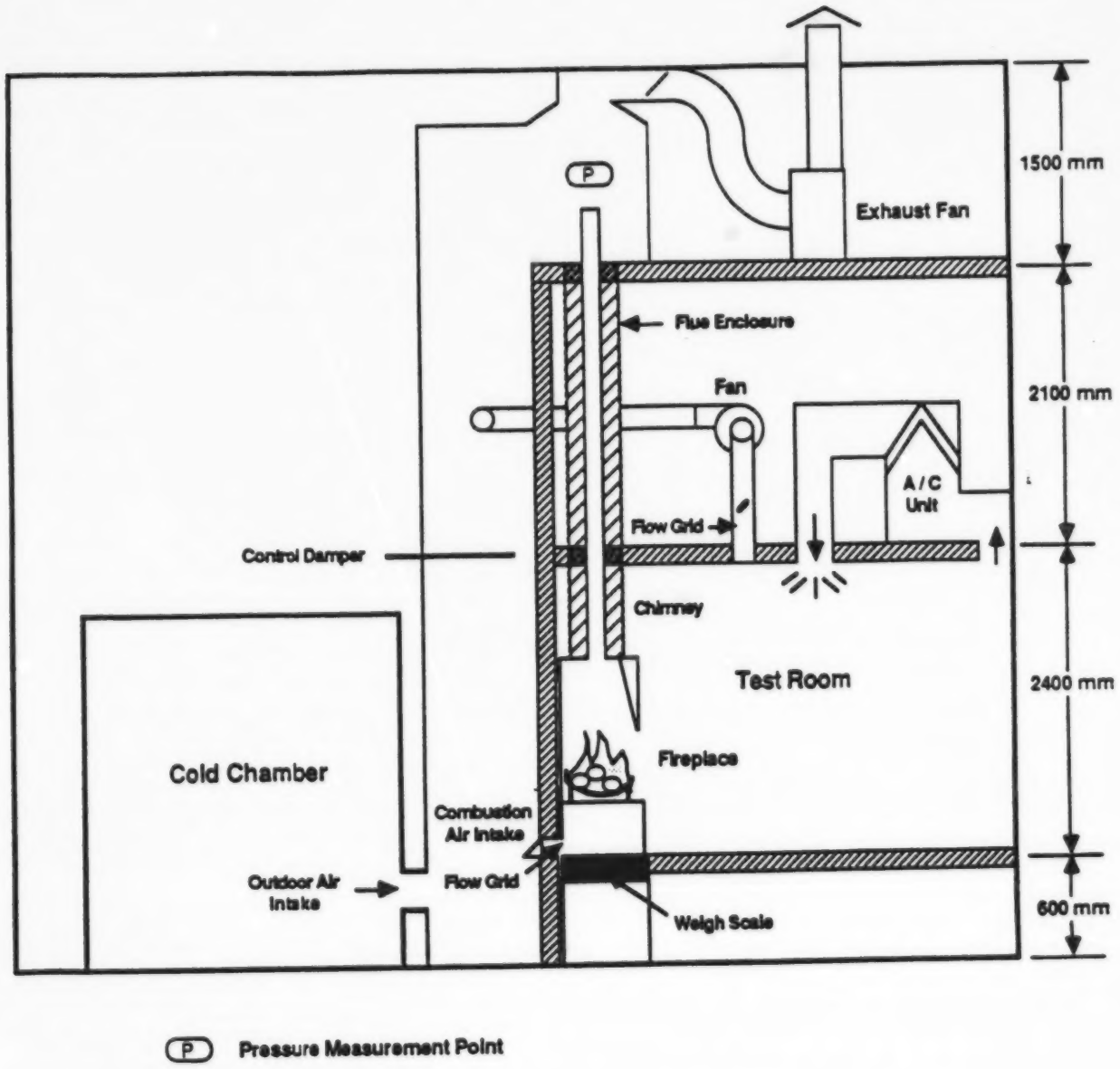


Figure 1: Cross Section of Fireplace Test Facility

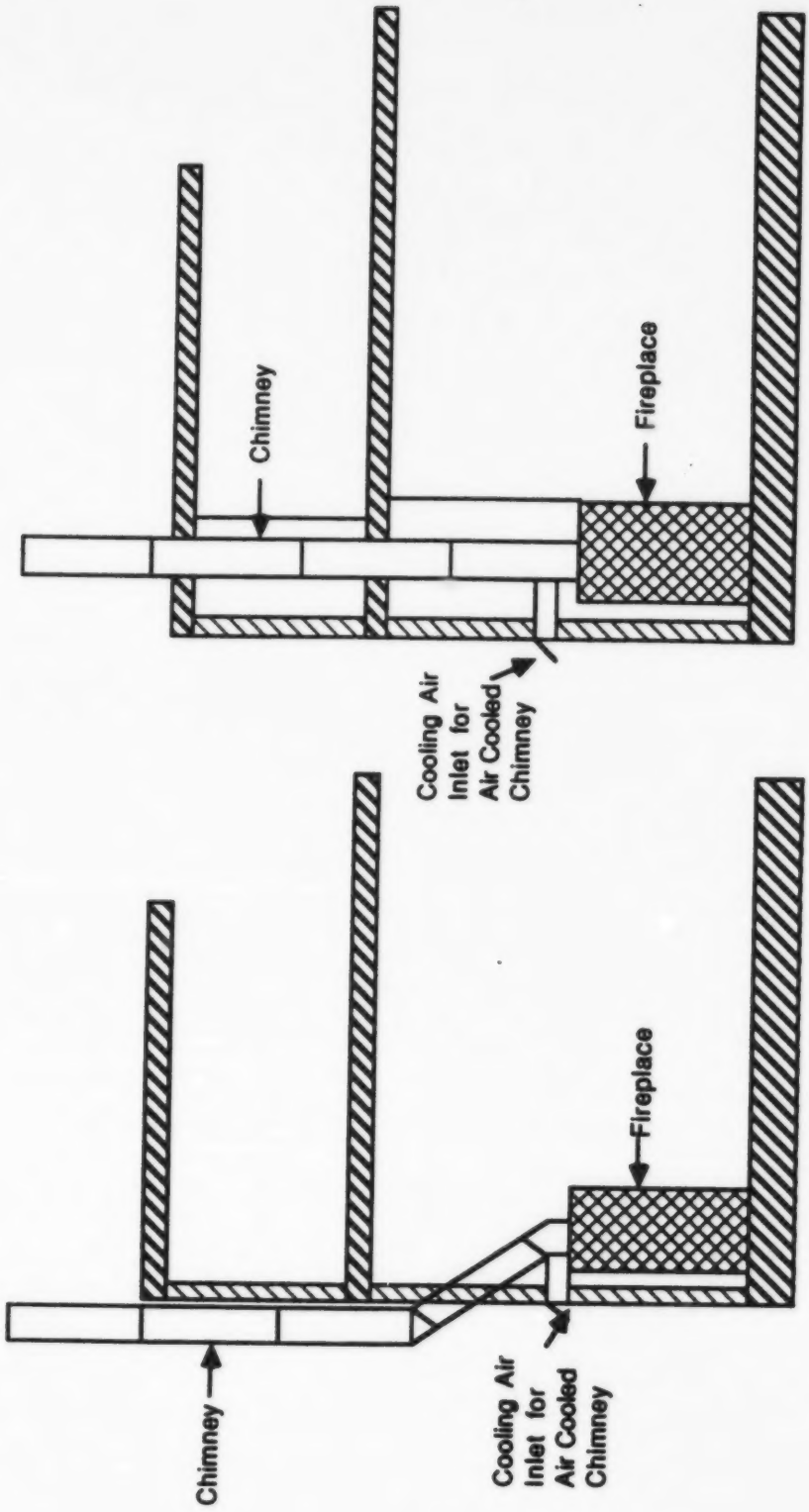


Figure 2: Diagrams of Chimney Installations

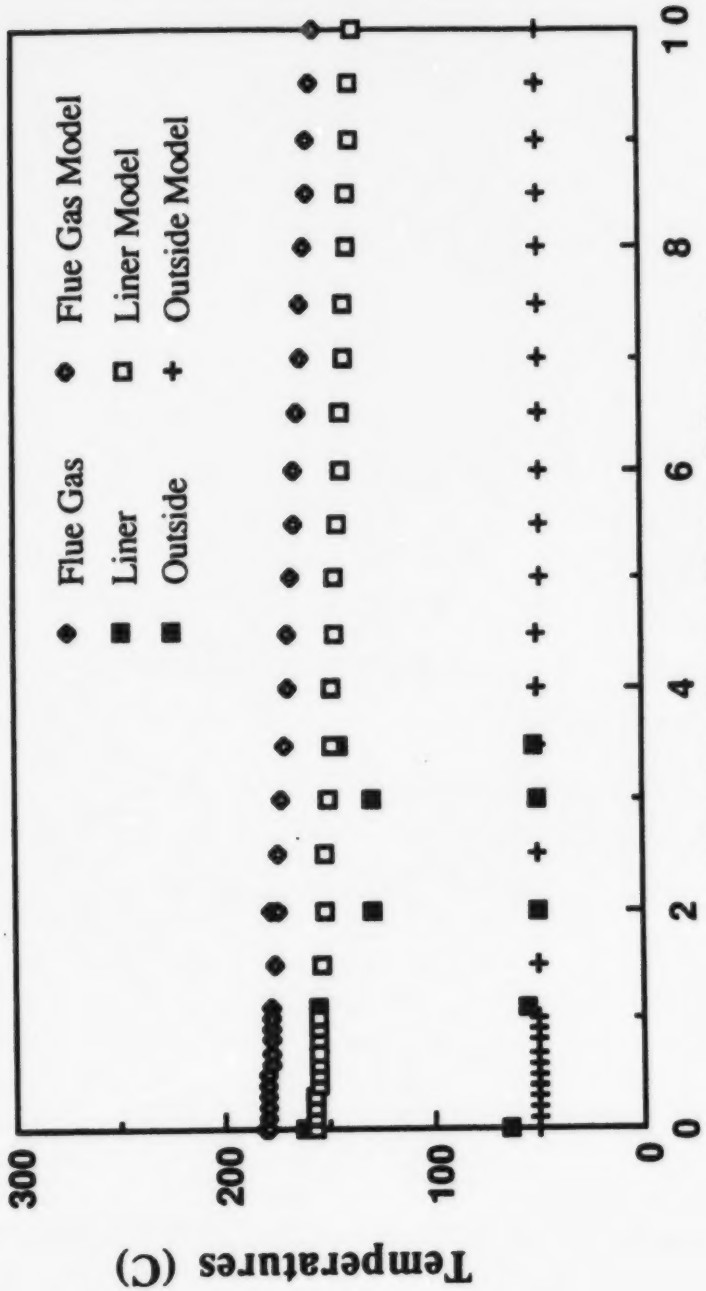


Figure 3: Type A Chimney Temperatures

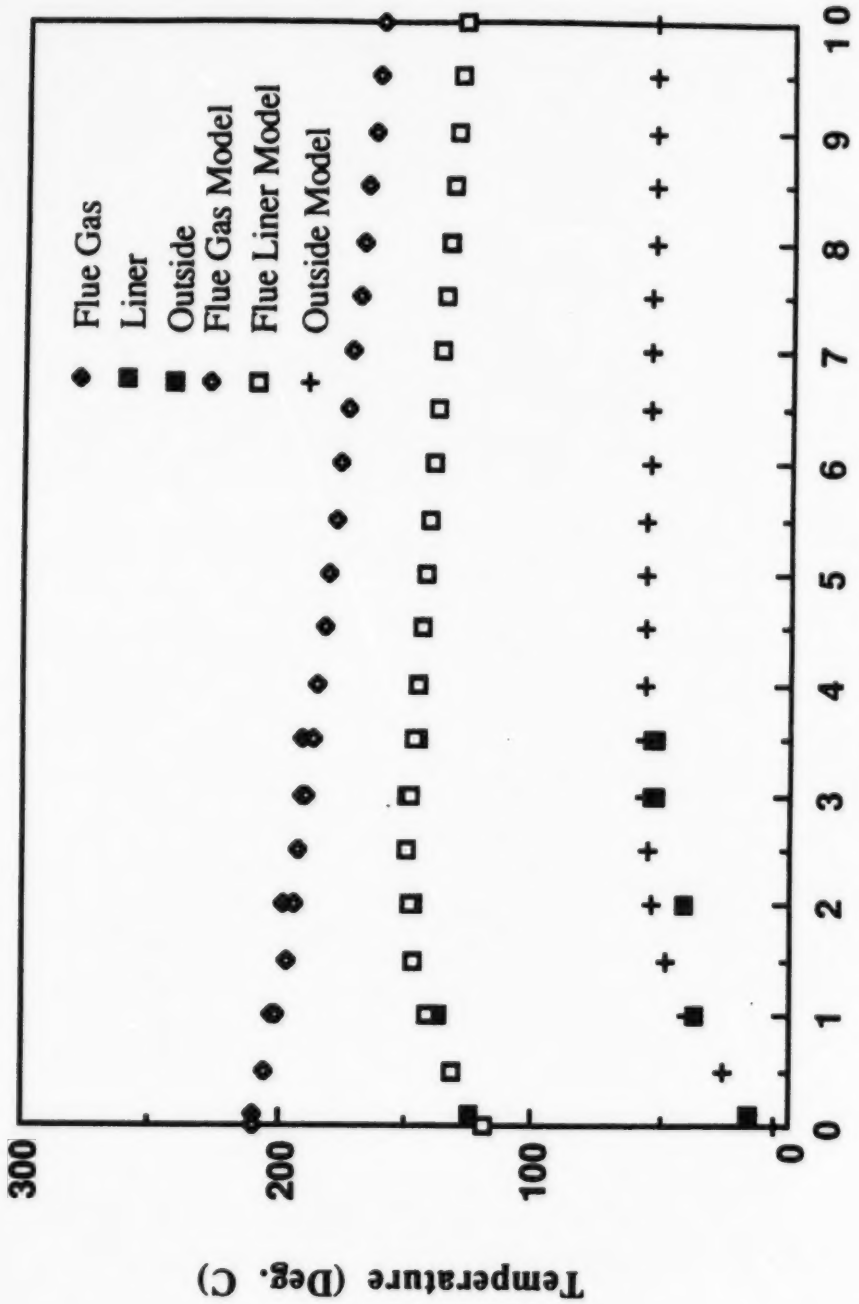


Figure 4: Aircooled Chimney Temperatures

The cooling airflow up the air-cooled chimney appeared to be in the range of 5 to 9 L/s for most cases. This would give an average velocity of 0.12 to 0.2 m/s compared to flue gas velocities in the order of 2 to 3 m/s. When the fire is burning, the mass flow rate of the cooling air is about 0.1 of the flue gas flow rate. Therefore, the heat given up from the flue gas by a temperature drop of 1°C would raise the temperature of the cooling air by 10°C. Figure 5 shows temperature in the air-cooled chimney for various cooling air temperatures, outdoor temperatures and flue flow rate. In 5(a), (b) and (c) the flue gas mass flow rate is about seven times the cooling air mass flow rate. In 5(a), in the first one metre of the chimney, the cooling air temperature increases by 73°C, while the flue gas temperature drops by 10°C. In 5(d) the flue gas to cooling air mass flow ratio is 28:1. In this case a cooling temperature rise of 52°C corresponds to a flue gas temperature drop of about 20°C. Going from a cooling air inlet temperature of 20°C down to a temperature of -40°C results in about a 4°C lower flue gas temperature. With the air-cooled chimney, the outside surface temperature at the base of the chimney is lower than that of the insulated chimneys. Therefore, heat loss from the chimney to the surroundings is lower for the air-cooled chimney. The cooling air entering the chimney is partially heated by energy that is conducted out through the wall of an insulated chimney. Figure 6 shows the projected energy flows for the insulated and air-cooled chimneys.

The overall heat transfer coefficient (U-value) was estimated for each of the chimneys by use of a simplified heat loss model. The heat loss was calculated using the equation:

$$Q = UA\Delta T$$

where Q is heat loss in watts

U is heat transfer coefficient $W/(m^2C)$

A is area m^2

ΔT is temperature difference between two points

Appendix 1 contains sample printouts of the equations used for the model in a computer spreadsheet format. Values of U were estimated from information in the ASHRAE Handbook of Fundamentals. Temperatures on flue surfaces, outside surfaces, and temperature drop of the flue gas due to heat loss were then calculated, and values compared with the experimental results. Using this method, it was estimated that the overall U-values for the 3 chimneys, based on inside surface area, are as follows:

Air-cooled	$U = 6.5$ W/(m^{2}C)
Type A	$U = 4$ W/(m^{2}C)
650	$U = 2.7$ W/(m^{2}C)

These values are approximate, and could easily vary from actual values by $\pm$ 0.5 W/(m^{2}C) or more, due to the fluctuating flue gas temperatures and flow rates encountered in the testing.

Appendix 2 contains some sample printouts of the model for each of the chimney types tested. For the insulated chimneys, the heat loss will depend on flue gas flow rate. For the air-cooled chimney, heat loss rate will depend on flue flow rate, cooling airflow rate and cooling air temperature. The interior surface temperatures of the flue in the air-cooled chimney appeared to respond to fluctuations in the flue gas temperature more quickly than the type A or 650 chimneys. The 650 chimney showed the least response of flue surface temperature to flue gas fluctuations.

Figures 7 to 9 show temperature for test runs for each of the chimney types tested.

During cool down, the flue surface temperature of the air-cooled chimney stayed below the flue gas temperature in most cases. In the type A and 650 chimneys, heat stored in the chimneys allowed the flue surface temperature to stay above the flue gas temperature during part of the cool down period.

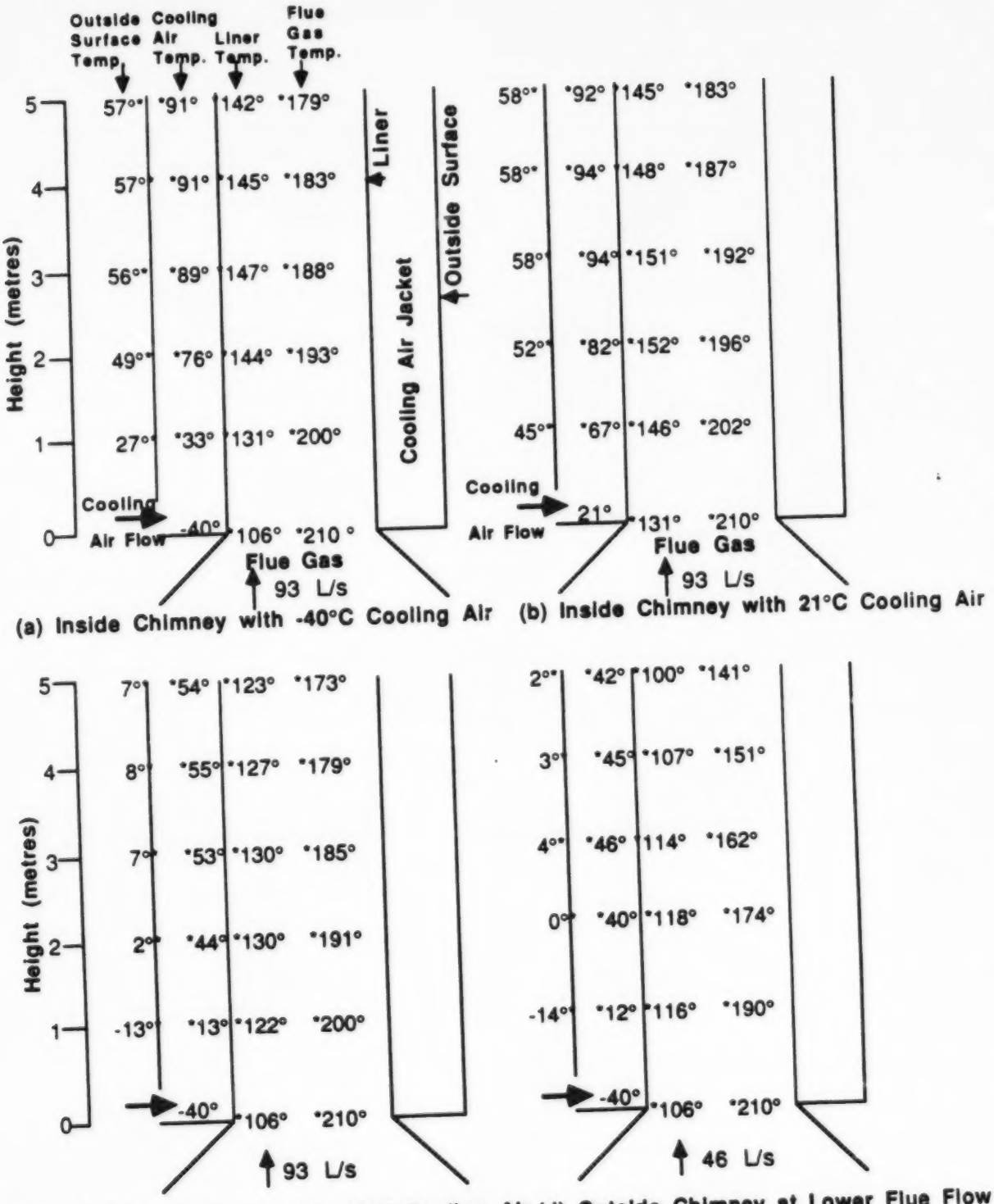
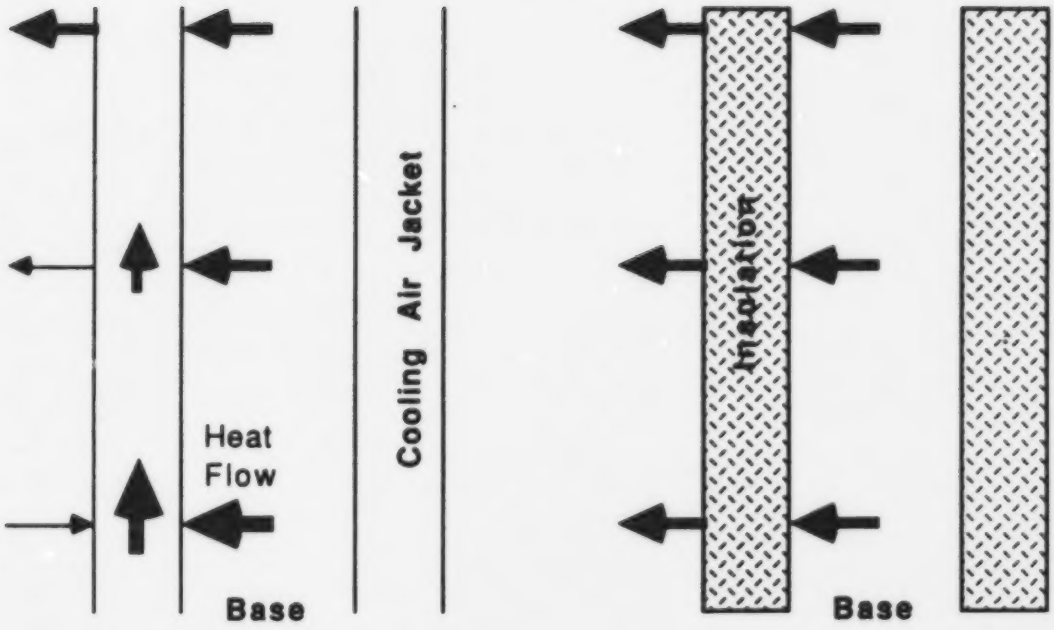


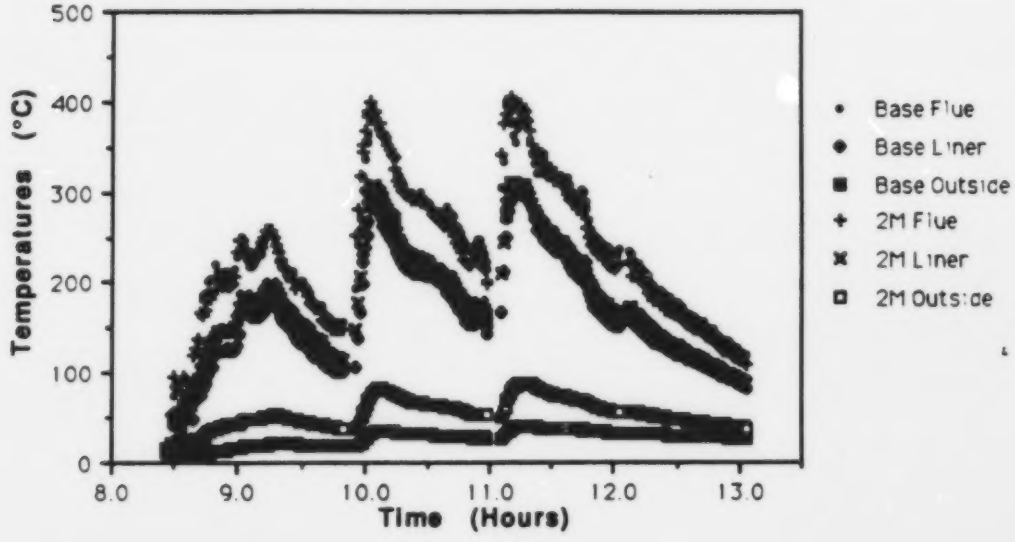
Figure 5: Temperatures in Air Cooled Chimney (from Model)



(a) Air Cooled Chimney (b) Insulated Chimney

Figure 6: Comparison of Heat Flows In Air-Cooled and Insulated Chimneys

Figure 7: Temperatures in Air Cooled Chimney (Test 5)



(b) Expanded Section

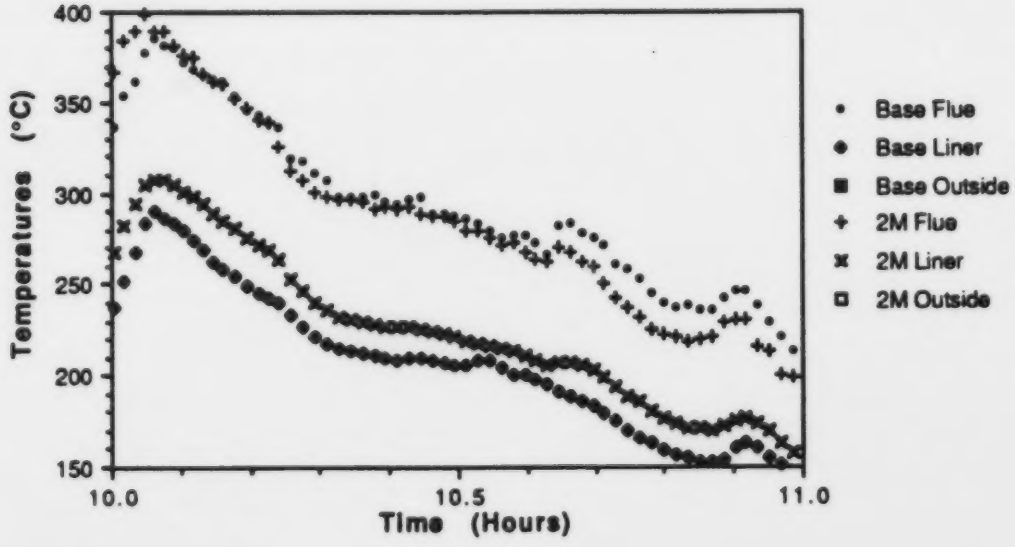
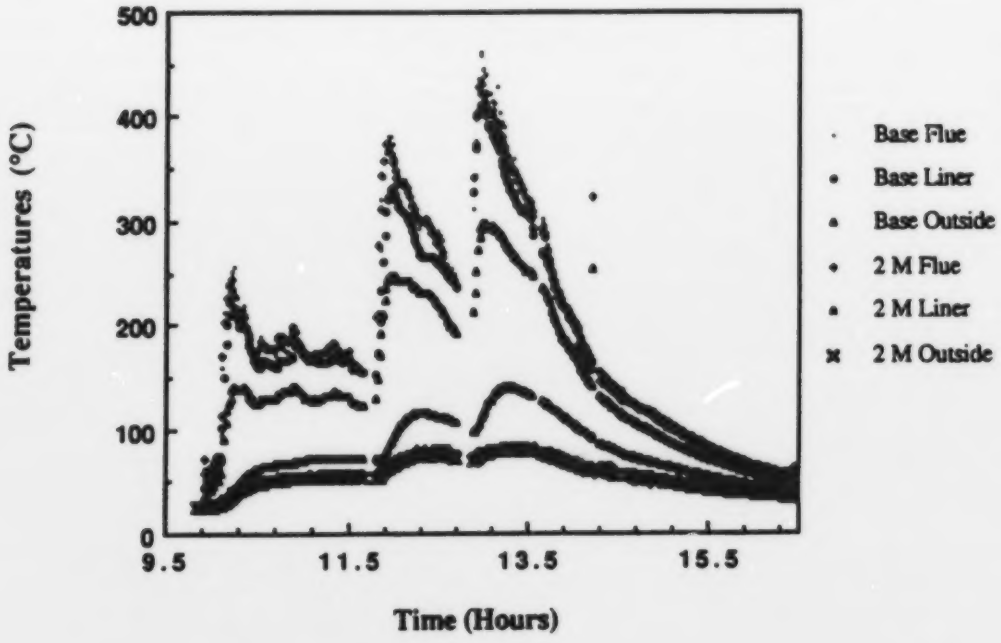


Figure 8: Temperatures In Type A Chimney (Test 7)



(b) Expanded Section

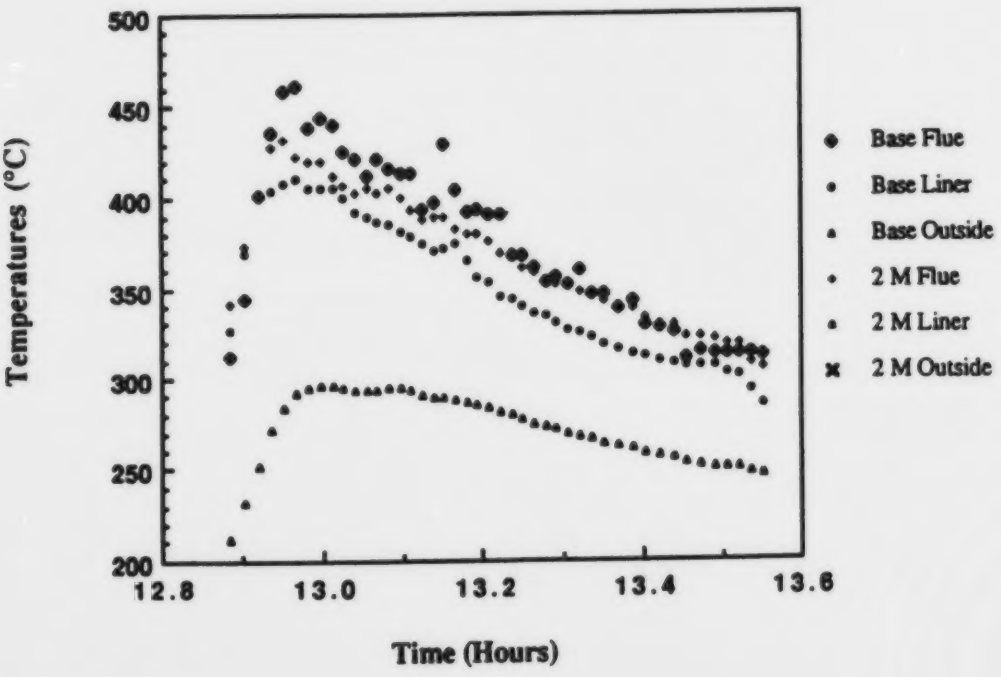
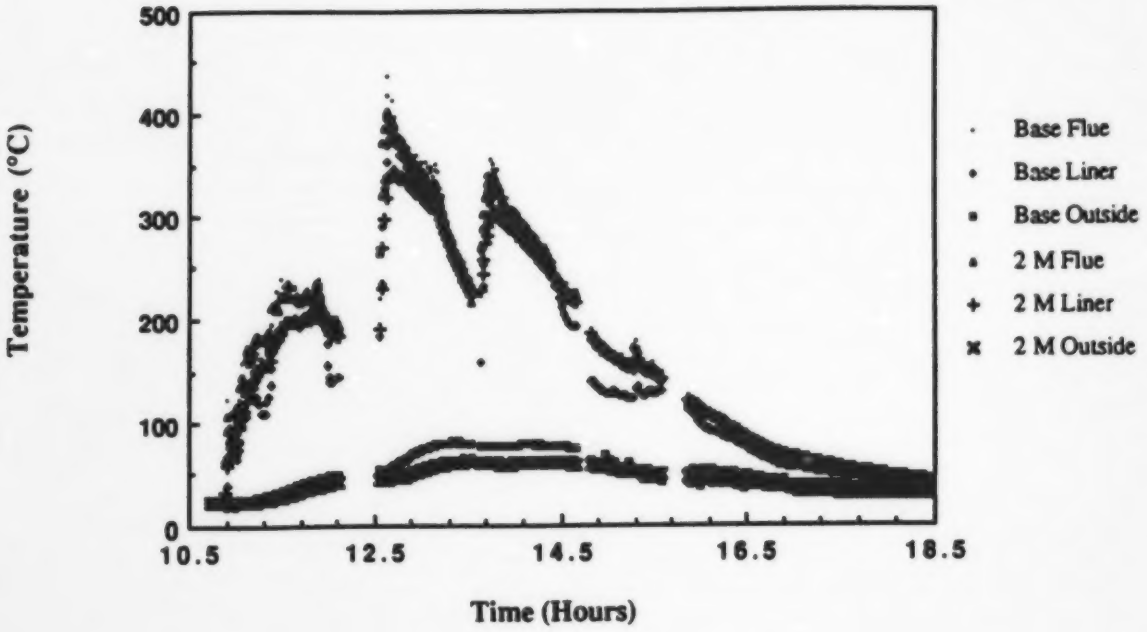
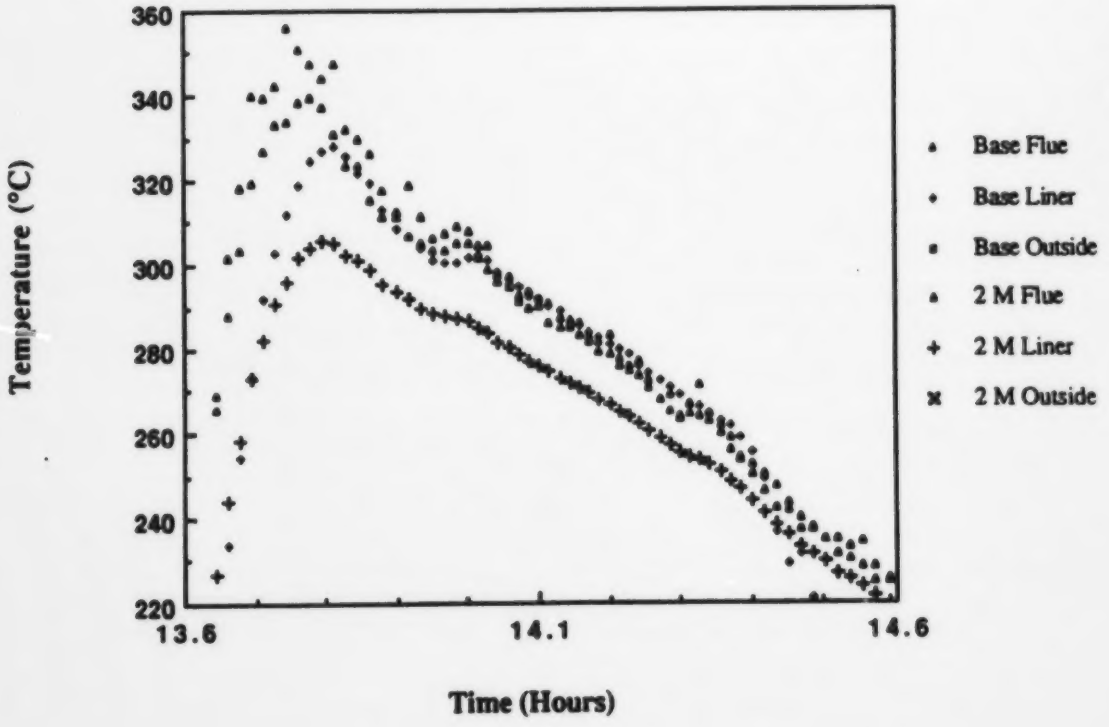


Figure 9: Temperatures in 650 Chimney (Test 11)



(b): Expanded Section



4.0 DISCUSSION OF RESULTS

The air-cooled chimney appears to perform better at high flue mass flow rates, where heat loss from the flue gas does not reduce flue gas temperatures as much as at low flue gas flow rates. This appears to be most appropriate for the operating characteristics of the fireplace used in these tests. If the flue gas temperature is low to begin with, and flue gas flow rates are also low, a significant flue gas temperature drop could occur. This could be a major problem for chimneys connected to wood appliances which can operate at very low burn rates, such as Fireplaces C and D described in ORTECH Report ESC-89-18. The higher heat loss rate of the air-cooled chimney produces lower surface temperatures on the flue liner than for the Type A and 650°C chimneys. This could promote increased formation of creosote deposits on the flue surface. The air-cooled chimney also has less mass for heat storage, which means that flue surface temperatures follow changes in flue gas temperatures more closely than in the Type A and 650°C chimneys. This effect is apparent in the expanded sections of Figures 7, 8 and 9. In the 650°C chimney, the flue liner temperatures change gradually, while for the air-cooled chimney, flue liner temperature fluctuations are much greater. Also, the flue liner temperatures in the air-cooled chimney always stay below the flue gas temperature, even during cool down. For the Type A and 650°C chimneys, the flue gas temperatures and liner temperatures become very close during cool down. In systems where spillage is a problem during cool down, the air-cooled chimney will have a faster reduction in draft during cool down, and therefore will likely be prone to spillage earlier in the cool down cycle.

Another factor resulting from the higher heat loss rate of the air-cooled chimney is the higher exterior surface temperatures of this chimney near the top, as compared to the Type A and 650°C chimneys. With the insulated chimneys, the highest exterior temperatures occur at the base of the chimney. For the air-cooled chimney, the highest exterior temperatures will more likely occur about 3 metres above the base of the flue. Therefore, chimney enclosure construction might need to be different for the air-cooled chimney, as compared to insulated chimneys.

The results of this work might be useful in conjunction with computer simulator models for predicting performance at conditions other than those tested.

APPENDIX 1

EQUATIONS USED IN CHIMNEY MODEL

Air-Cooled Chimney Model

	A	B	C	D	E
3					12
4	Height Above	Flue Gas,	Cooling air	Outdoor air	Flue Liner
5	Base M	Temp C	Temp C	Temp C	Temp C
6	0	210	20	21	=B6-I6/(E$3*(A7-A6)*PI()*(8*25.4)/1000)
7	=A6+0.1	=B6-(I6/(G6*293/(B$6+273)*1.2))	=C6+((I6-J6)/(H6*1.2*	=D6+0.1	=B7-I7/(E$3*(A8-A7)*PI()*(8*25.4)/1000)
8	=A7+0.1	=B7-(I7/(G7*293/(B$6+273)*1.2))	=C7+((I7-J7)/(H7*1.2*	=D7+0.1	=B8-I8/(E$3*(A9-A8)*PI()*(8*25.4)/1000)
9	=A8+0.1	=B8-(I8/(G8*293/(B$6+273)*1.2))	=C8+((I8-J8)/(H8*1.2*	=D8+0.1	=B9-I9/(E$3*(A10-A9)*PI()*(8*25.4)/1000)
10	=A9+0.1	=B9-(I9/(G9*293/(B$6+273)*1.2))	=C9+((I9-J9)/(H9*1.2*	=D9+0.1	=B10-I10/(E$3*(A11-A10)*PI()*(8*25.4)/1000)
11	=A10+0.1	=B10-(I10/(G10*293/(B$6+273)*1.2))	=C10+((I10-J10)/(H10	=D10+0.1	=B11-I11/(E$3*(A12-A11)*PI()*(8*25.4)/1000)
12	=A11+0.1	=B11-(I11/(G11*293/(B$6+273)*1.2))	=C11+((I11-J11)/(H11	=D11+0.1	=B12-I12/(E$3*(A13-A12)*PI()*(8*25.4)/1000)
13	=A12+0.1	=B12-(I12/(G12*293/(B$6+273)*1.2))	=C12+((I12-J12)/(H12	=D12+0.1	=B13-I13/(E$3*(A14-A13)*PI()*(8*25.4)/1000)
14	=A13+0.1	=B13-(I13/(G13*293/(B$6+273)*1.2))	=C13+((I13-J13)/(H13	=D13+0.1	=B14-I14/(E$3*(A15-A14)*PI()*(8*25.4)/1000)
15	=A14+0.1	=B14-(I14/(G14*293/(B$6+273)*1.2))	=C14+((I14-J14)/(H14	=D14+0.1	=B15-I15/(E$3*(A16-A15)*PI()*(8*25.4)/1000)
16	=A15+0.1	=B15-(I15/(G15*293/(B$6+273)*1.2))	=C15+((I15-J15)/(H15	=D15+0.1	=B16-I16/(E$3*(A17-A16)*PI()*(8*25.4)/1000)
17	=A16+0.5	=B16-(I16/(G16*293/(B$6+273)*1.2))	=C16+((I16-J16)/(H16	=D16+0.1	=B17-I17/(E$3*(A18-A17)*PI()*(8*25.4)/1000)
18	=A17+0.5	=B17-(I17/(G17*293/(B$6+273)*1.2))	=C17+((I17-J17)/(H17	=D17+0.1	=B18-I18/(E$3*(A19-A18)*PI()*(8*25.4)/1000)
19	=A18+0.5	=B18-(I18/(G18*293/(B$6+273)*1.2))	=C18+((I18-J18)/(H18	=D18+0.1	=B19-I19/(E$3*(A20-A19)*PI()*(8*25.4)/1000)
20	=A19+0.5	=B19-(I19/(G19*293/(B$6+273)*1.2))	=C19+((I19-J19)/(H19	=D19+0.1	=B20-I20/(E$3*(A21-A20)*PI()*(8*25.4)/1000)
21	=A20+0.5	=B20-(I20/(G20*293/(B$6+273)*1.2))	=C20+((I20-J20)/(H20	=D20+0.1	=B21-I21/(E$3*(A22-A21)*PI()*(8*25.4)/1000)
22	=A21+0.5	=B21-(I21/(G21*293/(B$6+273)*1.2))	=C21+((I21-J21)/(H21	=D21+0.1	=B22-I22/(E$3*(A23-A22)*PI()*(8*25.4)/1000)
23	=A22+0.5	=B22-(I22/(G22*293/(B$6+273)*1.2))	=C22+((I22-J22)/(H22	=D22+0.1	=B23-I23/(E$3*(A24-A23)*PI()*(8*25.4)/1000)
24	=A23+0.5	=B23-(I23/(G23*293/(B$6+273)*1.2))	=C23+((I23-J23)/(H23	=D23+0.1	=B24-I24/(E$3*(A25-A24)*PI()*(8*25.4)/1000)
25	=A24+0.5	=B24-(I24/(G24*293/(B$6+273)*1.2))	=C24+((I24-J24)/(H24	=D24+0.1	=B25-I25/(E$3*(A26-A25)*PI()*(8*25.4)/1000)
26	=A25+0.5	=B25-(I25/(G25*293/(B$6+273)*1.2))	=C25+((I25-J25)/(H25	=D25+0.1	=B26-I26/(E$3*(A27-A26)*PI()*(8*25.4)/1000)
27	=A26+0.5	=B26-(I26/(G26*293/(B$6+273)*1.2))	=C26+((I26-J26)/(H26	=D26+0.1	=B27-I27/(E$3*(A28-A27)*PI()*(8*25.4)/1000)
28	=A27+0.5	=B27-(I27/(G27*293/(B$6+273)*1.2))	=C27+((I27-J27)/(H27	=D27+0.1	=B28-I28/(E$3*(A29-A28)*PI()*(8*25.4)/1000)
29	=A28+0.5	=B28-(I28/(G28*293/(B$6+273)*1.2))	=C28+((I28-J28)/(H28	=D28+0.1	=B29-I29/(E$3*(A30-A29)*PI()*(8*25.4)/1000)
30	=A29+0.5	=B29-(I29/(G29*293/(B$6+273)*1.2))	=C29+((I29-J29)/(H29	=D29+0.1	=B30-I30/(E$3*(A31-A30)*PI()*(8*25.4)/1000)
31	=A30+0.5	=B30-(I30/(G30*293/(B$6+273)*1.2))	=C30+((I30-J30)/(H30	=D30+0.1	=B31-I31/(E$3*(A32-A31)*PI()*(8*25.4)/1000)
32	=A31+0.5	=B31-(I31/(G31*293/(B$6+273)*1.2))	=C31+((I31-J31)/(H31	=D31+0.1	=B32-I32/(E$3*(A33-A32)*PI()*(8*25.4)/1000)
33	=A32+0.5	=B32-(I32/(G32*293/(B$6+273)*1.2))	=C32+((I32-J32)/(H32	=D32+0.1	=B33-I33/(E$3*(A34-A33)*PI()*(8*25.4)/1000)
34	=A33+0.5	=B33-(I33/(G33*293/(B$6+273)*1.2))	=C33+((I33-J33)/(H33	=D33+0.1	=B34-I34/(E$3*(A35-A34)*PI()*(8*25.4)/1000)
35	=A34+0.5	=B34-(I34/(G34*293/(B$6+273)*1.2))	=C34+((I34-J34)/(H34	=D34+0.1	=B35-I35/(E$3*(A36-A35)*PI()*(8*25.4)/1000)
36	=A35+0.5	=B35-(I35/(G35*293/(B$6+273)*1.2))	=C35+((I35-J35)/(H35	=D35+0.1	=B36-I36/(E$3*(A37-A36)*PI()*(8*25.4)/1000)
37	=A36+0.5	=B36-(I36/(G36*293/(B$6+273)*1.2))	=C36+((I36-J36)/(H36	=D36+0.1	=B37-I37/(E$3*(A38-A37)*PI()*(8*25.4)/1000)
38	=A37+0.5	=B37-(I37/(G37*293/(B$6+273)*1.2))	=C37+((I37-J37)/(H37	=D37+0.1	=B38-I38/(E$3*(A39-A38)*PI()*(8*25.4)/1000)
39	=A38+0.5	=B38-(I38/(G38*293/(B$6+273)*1.2))	=C38+((I38-J38)/(H38	=D38+0.1	=B39-I39/(E$3*(A40-A39)*PI()*(8*25.4)/1000)
40	=A39+0.5	=B39-(I39/(G39*293/(B$6+273)*1.2))	=C39+((I39-J39)/(H39	=D39+0.1	=B40-I40/(E$3*(A41-A40)*PI()*(8*25.4)/1000)
41	=A40+0.5	=B40-(I40/(G40*293/(B$6+273)*1.2))	=C40+((I40-J40)/(H40	=D40+0.1	=B41-I41/(E$3*(A42-A41)*PI()*(8*25.4)/1000)
42	=A41+0.5	=B41-(I41/(G41*293/(B$6+273)*1.2))	=C41+((I41-J41)/(H41	=D41+0.1	=B42-I42/(E$3*(A43-A42)*PI()*(8*25.4)/1000)
43	=A42+0.5	=B42-(I42/(G42*293/(B$6+273)*1.2))	=C42+((I42-J42)/(H42	=D42+0.1	=B43-I43/(E$3*(A44-A43)*PI()*(8*25.4)/1000)
44	=A43+0.5	=B43-(I43/(G43*293/(B$6+273)*1.2))	=C43+((I43-J43)/(H43	=D43+0.1	=B44-I44/(E$3*(A45-A44)*PI()*(8*25.4)/1000)
45	=A44+0.5	=B44-(I44/(G44*293/(B$6+273)*1.2))	=C44+((I44-J44)/(H44	=D44+0.1	=B45-I45/(E$3*(A46-A45)*PI()*(8*25.4)/1000)

	F	G	H	I	J
3				Ui=6.5	Uo=4.5
4	Outside Surf	Flue Flow	Cooling Flow	Heat Loss	Exterior
5	Temp C	L/s	L/s	Watts	Heat loss
6	=(C6+D6)/2	=93/2	8	=$I$2*(B6-C6)*(A7-A6)*PI()*(8*25.4)/1000	=$J$2*(A7-A6)*PI()*(12*25.4/1000)*(C6-D6)
7	=(C7+D7)/2	=G$6	=H$6	=$I$2*(B7-C7)*(A8-A7)*PI()*(8*25.4)/1000	=$J$2*(A8-A7)*PI()*(12*25.4/1000)*(C7-D7)
8	=(C8+D8)/2	=G$6	=H$6	=$I$2*(B8-C8)*(A9-A8)*PI()*(8*25.4)/1000	=$J$2*(A9-A8)*PI()*(12*25.4/1000)*(C8-D8)
9	=(C9+D9)/2	=G$6	=H$6	=$I$2*(B9-C9)*(A10-A9)*PI()*(8*25.4)/1000	=$J$2*(A10-A9)*PI()*(12*25.4/1000)*(C9-D9)
10	=(C10+D10)/2	=G$6	=H$6	=$I$2*(B10-C10)*(A11-A10)*PI()*(8*25.4)/1000	=$J$2*(A11-A10)*PI()*(12*25.4/1000)*(C10-D10)
11	=(C11+D11)/2	=G$6	=H$6	=$I$2*(B11-C11)*(A12-A11)*PI()*(8*25.4)/1000	=$J$2*(A12-A11)*PI()*(12*25.4/1000)*(C11-D11)
12	=(C12+D12)/2	=G$6	=H$6	=$I$2*(B12-C12)*(A13-A12)*PI()*(8*25.4)/1000	=$J$2*(A13-A12)*PI()*(12*25.4/1000)*(C12-D12)
13	=(C13+D13)/2	=G$6	=H$6	=$I$2*(B13-C13)*(A14-A13)*PI()*(8*25.4)/1000	=$J$2*(A14-A13)*PI()*(12*25.4/1000)*(C13-D13)
14	=(C14+D14)/2	=G$6	=H$6	=$I$2*(B14-C14)*(A15-A14)*PI()*(8*25.4)/1000	=$J$2*(A15-A14)*PI()*(12*25.4/1000)*(C14-D14)
15	=(C15+D15)/2	=G$6	=H$6	=$I$2*(B15-C15)*(A16-A15)*PI()*(8*25.4)/1000	=$J$2*(A16-A15)*PI()*(12*25.4/1000)*(C15-D15)
16	=(C16+D16)/2	=G$6	=H$6	=$I$2*(B16-C16)*(A17-A16)*PI()*(8*25.4)/1000	=$J$2*(A17-A16)*PI()*(12*25.4/1000)*(C16-D16)
17	=(C17+D17)/2	=G$6	=H$6	=$I$2*(B17-C17)*(A18-A17)*PI()*(8*25.4)/1000	=$J$2*(A18-A17)*PI()*(12*25.4/1000)*(C17-D17)
18	=(C18+D18)/2	=G$6	=H$6	=$I$2*(B18-C18)*(A19-A18)*PI()*(8*25.4)/1000	=$J$2*(A19-A18)*PI()*(12*25.4/1000)*(C18-D18)
19	=(C19+D19)/2	=G$6	=H$6	=$I$2*(B19-C19)*(A20-A19)*PI()*(8*25.4)/1000	=$J$2*(A20-A19)*PI()*(12*25.4/1000)*(C19-D19)
20	=(C20+D20)/2	=G$6	=H$6	=$I$2*(B20-C20)*(A21-A20)*PI()*(8*25.4)/1000	=$J$2*(A21-A20)*PI()*(12*25.4/1000)*(C20-D20)
21	=(C21+D21)/2	=G$6	=H$6	=$I$2*(B21-C21)*(A22-A21)*PI()*(8*25.4)/1000	=$J$2*(A22-A21)*PI()*(12*25.4/1000)*(C21-D21)
22	=(C22+D22)/2	=G$6	=H$6	=$I$2*(B22-C22)*(A23-A22)*PI()*(8*25.4)/1000	=$J$2*(A23-A22)*PI()*(12*25.4/1000)*(C22-D22)
23	=(C23+D23)/2	=G$6	=H$6	=$I$2*(B23-C23)*(A24-A23)*PI()*(8*25.4)/1000	=$J$2*(A24-A23)*PI()*(12*25.4/1000)*(C23-D23)
24	=(C24+D24)/2	=G$6	=H$6	=$I$2*(B24-C24)*(A25-A24)*PI()*(8*25.4)/1000	=$J$2*(A25-A24)*PI()*(12*25.4/1000)*(C24-D24)
25	=(C25+D25)/2	=G$6	=H$6	=$I$2*(B25-C25)*(A26-A25)*PI()*(8*25.4)/1000	=$J$2*(A26-A25)*PI()*(12*25.4/1000)*(C25-D25)
26	=(C26+D26)/2	=G$6	=H$6	=$I$2*(B26-C26)*(A27-A26)*PI()*(8*25.4)/1000	=$J$2*(A27-A26)*PI()*(12*25.4/1000)*(C26-D26)
27	=(C27+D27)/2	=G$6	=H$6	=$I$2*(B27-C27)*(A28-A27)*PI()*(8*25.4)/1000	=$J$2*(A28-A27)*PI()*(12*25.4/1000)*(C27-D27)
28	=(C28+D28)/2	=G$6	=H$6	=$I$2*(B28-C28)*(A29-A28)*PI()*(8*25.4)/1000	=$J$2*(A29-A28)*PI()*(12*25.4/1000)*(C28-D28)
29	=(C29+D29)/2	=G$6	=H$6	=$I$2*(B29-C29)*(A30-A29)*PI()*(8*25.4)/1000	=$J$2*(A30-A29)*PI()*(12*25.4/1000)*(C29-D29)
30	=(C30+D30)/2	=G$6	=H$6	=$I$2*(B30-C30)*(A31-A30)*PI()*(8*25.4)/1000	=$J$2*(A31-A30)*PI()*(12*25.4/1000)*(C30-D30)
31	=(C31+D31)/2	=G$6	=H$6	=$I$2*(B31-C31)*(A32-A31)*PI()*(8*25.4)/1000	=$J$2*(A32-A31)*PI()*(12*25.4/1000)*(C31-D31)
32	=(C32+D32)/2	=G$6	=H$6	=$I$2*(B32-C32)*(A33-A32)*PI()*(8*25.4)/1000	=$J$2*(A33-A32)*PI()*(12*25.4/1000)*(C32-D32)
33	=(C33+D33)/2	=G$6	=H$6	=$I$2*(B33-C33)*(A34-A33)*PI()*(8*25.4)/1000	=$J$2*(A34-A33)*PI()*(12*25.4/1000)*(C33-D33)
34	=(C34+D34)/2	=G$6	=H$6	=$I$2*(B34-C34)*(A35-A34)*PI()*(8*25.4)/1000	=$J$2*(A35-A34)*PI()*(12*25.4/1000)*(C34-D34)
35	=(C35+D35)/2	=G$6	=H$6	=$I$2*(B35-C35)*(A36-A35)*PI()*(8*25.4)/1000	=$J$2*(A36-A35)*PI()*(12*25.4/1000)*(C35-D35)
36	=(C36+D36)/2	=G$6	=H$6	=$I$2*(B36-C36)*(A37-A36)*PI()*(8*25.4)/1000	=$J$2*(A37-A36)*PI()*(12*25.4/1000)*(C36-D36)
37	=(C37+D37)/2	=G$6	=H$6	=$I$2*(B37-C37)*(A38-A37)*PI()*(8*25.4)/1000	=$J$2*(A38-A37)*PI()*(12*25.4/1000)*(C37-D37)
38	=(C38+D38)/2	=G$6	=H$6	=$I$2*(B38-C38)*(A39-A38)*PI()*(8*25.4)/1000	=$J$2*(A39-A38)*PI()*(12*25.4/1000)*(C38-D38)
39	=(C39+D39)/2	=G$6	=H$6	=$I$2*(B39-C39)*(A40-A39)*PI()*(8*25.4)/1000	=$J$2*(A40-A39)*PI()*(12*25.4/1000)*(C39-D39)
40	=(C40+D40)/2	=G$6	=H$6	=$I$2*(B40-C40)*(A41-A40)*PI()*(8*25.4)/1000	=$J$2*(A41-A40)*PI()*(12*25.4/1000)*(C40-D40)
41	=(C41+D41)/2	=G$6	=H$6	=$I$2*(B41-C41)*(A42-A41)*PI()*(8*25.4)/1000	=$J$2*(A42-A41)*PI()*(12*25.4/1000)*(C41-D41)
42	=(C42+D42)/2	=G$6	=H$6	=$I$2*(B42-C42)*(A43-A42)*PI()*(8*25.4)/1000	=$J$2*(A43-A42)*PI()*(12*25.4/1000)*(C42-D42)
43	=(C43+D43)/2	=G$6	=H$6	=$I$2*(B43-C43)*(A44-A43)*PI()*(8*25.4)/1000	=$J$2*(A44-A43)*PI()*(12*25.4/1000)*(C43-D43)
44	=(C44+D44)/2	=G$6	=H$6	=$I$2*(B44-C44)*(A45-A44)*PI()*(8*25.4)/1000	=$J$2*(A45-A44)*PI()*(12*25.4/1000)*(C44-D44)
45	=(C45+D45)/2	=G$6	=H$6	=$I$2*(B45-C45)*(A46-A45)*PI()*(8*25.4)/1000	=$J$2*(A46-A45)*PI()*(12*25.4/1000)*(C45-D45)

	A	B	C	D
3				
4	Height Above	Flue Gas	Outdoor air	Flue Liner
5	Base M	Temp C	Temp C	Temp C
6	0	180	25	=B6-G6/(D$2*($A7-$A6)*PI()*(8*25.4)/1000)
7	=A6+0.1	=B6-(G6/(F6*293/(B$6+273)*1.2))	=C6+C$2*(A7-A6)	=B7-G7/(D$2*($A8-$A7)*PI()*(8*25.4)/1000)
8	=A7+0.1	=B7-(G7/(F7*293/(B$6+273)*1.2))	=C7+C$2*(A8-A7)	=B8-G8/(D$2*($A9-$A8)*PI()*(8*25.4)/1000)
9	=A8+0.1	=B8-(G8/(F8*293/(B$6+273)*1.2))	=C8+C$2*(A9-A8)	=B9-G9/(D$2*($A10-$A9)*PI()*(8*25.4)/1000)
10	=A9+0.1	=B9-(G9/(F9*293/(B$6+273)*1.2))	=C9+C$2*(A10-A9)	=B10-G10/(D$2*($A11-$A10)*PI()*(8*25.4)/1000)
11	=A10+0.1	=B10-(G10/(F10*293/(B$6+273)*1.2))	=C10+C$2*(A11-A10)	=B11-G11/(D$2*($A12-$A11)*PI()*(8*25.4)/1000)
12	=A11+0.1	=B11-(G11/(F11*293/(B$6+273)*1.2))	=C11+C$2*(A12-A11)	=B12-G12/(D$2*($A13-$A12)*PI()*(8*25.4)/1000)
13	=A12+0.1	=B12-(G12/(F12*293/(B$6+273)*1.2))	=C12+C$2*(A13-A12)	=B13-G13/(D$2*($A14-$A13)*PI()*(8*25.4)/1000)
14	=A13+0.1	=B13-(G13/(F13*293/(B$6+273)*1.2))	=C13+C$2*(A14-A13)	=B14-G14/(D$2*($A15-$A14)*PI()*(8*25.4)/1000)
15	=A14+0.1	=B14-(G14/(F14*293/(B$6+273)*1.2))	=C14+C$2*(A15-A14)	=B15-G15/(D$2*($A16-$A15)*PI()*(8*25.4)/1000)
16	=A15+0.1	=B15-(G15/(F15*293/(B$6+273)*1.2))	=C15+C$2*(A16-A15)	=B16-G16/(D$2*($A17-$A16)*PI()*(8*25.4)/1000)
17	=A16+0.5	=B16-(G16/(F16*293/(B$6+273)*1.2))	=C16+C$2*(A17-A16)	=B17-G17/(D$2*($A18-$A17)*PI()*(8*25.4)/1000)
18	=A17+0.5	=B17-(G17/(F17*293/(B$6+273)*1.2))	=C17+C$2*(A18-A17)	=B18-G18/(D$2*($A19-$A18)*PI()*(8*25.4)/1000)
19	=A18+0.5	=B18-(G18/(F18*293/(B$6+273)*1.2))	=C18+C$2*(A19-A18)	=B19-G19/(D$2*($A20-$A19)*PI()*(8*25.4)/1000)
20	=A19+0.5	=B19-(G19/(F19*293/(B$6+273)*1.2))	=C19+C$2*(A20-A19)	=B20-G20/(D$2*($A21-$A20)*PI()*(8*25.4)/1000)
21	=A20+0.5	=B20-(G20/(F20*293/(B$6+273)*1.2))	=C20+C$2*(A21-A20)	=B21-G21/(D$2*($A22-$A21)*PI()*(8*25.4)/1000)
22	=A21+0.5	=B21-(G21/(F21*293/(B$6+273)*1.2))	=C21+C$2*(A22-A21)	=B22-G22/(D$2*($A23-$A22)*PI()*(8*25.4)/1000)
23	=A22+0.5	=B22-(G22/(F22*293/(B$6+273)*1.2))	=C22+C$2*(A23-A22)	=B23-G23/(D$2*($A24-$A23)*PI()*(8*25.4)/1000)
24	=A23+0.5	=B23-(G23/(F23*293/(B$6+273)*1.2))	=C23+C$2*(A24-A23)	=B24-G24/(D$2*($A25-$A24)*PI()*(8*25.4)/1000)
25	=A24+0.5	=B24-(G24/(F24*293/(B$6+273)*1.2))	=C24+C$2*(A25-A24)	=B25-G25/(D$2*($A26-$A25)*PI()*(8*25.4)/1000)
26	=A25+0.5	=B25-(G25/(F25*293/(B$6+273)*1.2))	=C25+C$2*(A26-A25)	=B26-G26/(D$2*($A27-$A26)*PI()*(8*25.4)/1000)
27	=A26+0.5	=B26-(G26/(F26*293/(B$6+273)*1.2))	=C26+C$2*(A27-A26)	=B27-G27/(D$2*($A28-$A27)*PI()*(8*25.4)/1000)
28	=A27+0.5	=B27-(G27/(F27*293/(B$6+273)*1.2))	=C27+C$2*(A28-A27)	=B28-G28/(D$2*($A29-$A28)*PI()*(8*25.4)/1000)
29	=A28+0.5	=B28-(G28/(F28*293/(B$6+273)*1.2))	=C28+C$2*(A29-A28)	=B29-G29/(D$2*($A30-$A29)*PI()*(8*25.4)/1000)
30	=A29+0.5	=B29-(G29/(F29*293/(B$6+273)*1.2))	=C29+C$2*(A30-A29)	=B30-G30/(D$2*($A31-$A30)*PI()*(8*25.4)/1000)
31	=A30+0.5	=B30-(G30/(F30*293/(B$6+273)*1.2))	=C30+C$2*(A31-A30)	=B31-G31/(D$2*($A32-$A31)*PI()*(8*25.4)/1000)
32	=A31+0.5	=B31-(G31/(F31*293/(B$6+273)*1.2))	=C31+C$2*(A32-A31)	=B32-G32/(D$2*($A33-$A32)*PI()*(8*25.4)/1000)
33	=A32+0.5	=B32-(G32/(F32*293/(B$6+273)*1.2))	=C32+C$2*(A33-A32)	=B33-G33/(D$2*($A34-$A33)*PI()*(8*25.4)/1000)
34	=A33+0.5	=B33-(G33/(F33*293/(B$6+273)*1.2))	=C33+C$2*(A34-A33)	=B34-G34/(D$2*($A35-$A34)*PI()*(8*25.4)/1000)
35	=A34+0.5	=B34-(G34/(F34*293/(B$6+273)*1.2))	=C34+C$2*(A35-A34)	=B35-G35/(D$2*($A36-$A35)*PI()*(8*25.4)/1000)
36	=A35+0.5	=B35-(G35/(F35*293/(B$6+273)*1.2))	=C35+C$2*(A36-A35)	=B36-G36/(D$2*($A37-$A36)*PI()*(8*25.4)/1000)
37	=A36+0.5	=B36-(G36/(F36*293/(B$6+273)*1.2))	=C36+C$2*(A37-A36)	=B37-G37/(D$2*($A38-$A37)*PI()*(8*25.4)/1000)
38	=A37+0.5	=B37-(G37/(F37*293/(B$6+273)*1.2))	=C37+C$2*(A38-A37)	=B38-G38/(D$2*($A39-$A38)*PI()*(8*25.4)/1000)
39	=A38+0.5	=B38-(G38/(F38*293/(B$6+273)*1.2))	=C38+C$2*(A39-A38)	=B39-G39/(D$2*($A40-$A39)*PI()*(8*25.4)/1000)
40	=A39+0.5	=B39-(G39/(F39*293/(B$6+273)*1.2))	=C39+C$2*(A40-A39)	=B40-G40/(D$2*($A41-$A40)*PI()*(8*25.4)/1000)
41	=A40+0.5	=B40-(G40/(F40*293/(B$6+273)*1.2))	=C40+C$2*(A41-A40)	=B41-G41/(D$2*($A42-$A41)*PI()*(8*25.4)/1000)
42	=A41+0.5	=B41-(G41/(F41*293/(B$6+273)*1.2))	=C41+C$2*(A42-A41)	=B42-G42/(D$2*($A43-$A42)*PI()*(8*25.4)/1000)
43	=A42+0.5	=B42-(G42/(F42*293/(B$6+273)*1.2))	=C42+C$2*(A43-A42)	=B43-G43/(D$2*($A44-$A43)*PI()*(8*25.4)/1000)
44	=A43+0.5	=B43-(G43/(F43*293/(B$6+273)*1.2))	=C43+C$2*(A44-A43)	=B44-G44/(D$2*($A45-$A44)*PI()*(8*25.4)/1000)
45	=A44+0.5	=B44-(G44/(F44*293/(B$6+273)*1.2))	=C44+C$2*(A45-A44)	=B45-G45/(D$2*($A46-$A45)*PI()*(8*25.4)/1000)

	E	F	G
3			2.7
4	Outside Surf	Flue Flow	Heat Loss
5	Temp C	L/s	Watts
6	=C6+G6/(E$2*($A7-$A6)*PI()*(12*25.4)/1000)	72	=$G$2*(B6-C6)*(A7-A6)*PI()*(8*25.4)/1000
7	=C7+G7/(E$2*($A8-$A7)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B7-C7)*(A8-A7)*PI()*(8*25.4)/1000
8	=C8+G8/(E$2*($A9-$A8)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B8-C8)*(A9-A8)*PI()*(8*25.4)/1000
9	=C9+G9/(E$2*($A10-$A9)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B9-C9)*(A10-A9)*PI()*(8*25.4)/1000
10	=C10+G10/(E$2*($A11-$A10)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B10-C10)*(A11-A10)*PI()*(8*25.4)/1000
11	=C11+G11/(E$2*($A12-$A11)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B11-C11)*(A12-A11)*PI()*(8*25.4)/1000
12	=C12+G12/(E$2*($A13-$A12)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B12-C12)*(A13-A12)*PI()*(8*25.4)/1000
13	=C13+G13/(E$2*($A14-$A13)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B13-C13)*(A14-A13)*PI()*(8*25.4)/1000
14	=C14+G14/(E$2*($A15-$A14)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B14-C14)*(A15-A14)*PI()*(8*25.4)/1000
15	=C15+G15/(E$2*($A16-$A15)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B15-C15)*(A16-A15)*PI()*(8*25.4)/1000
16	=C16+G16/(E$2*($A17-$A16)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B16-C16)*(A17-A16)*PI()*(8*25.4)/1000
17	=C17+G17/(E$2*($A18-$A17)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B17-C17)*(A18-A17)*PI()*(8*25.4)/1000
18	=C18+G18/(E$2*($A19-$A18)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B18-C18)*(A19-A18)*PI()*(8*25.4)/1000
19	=C19+G19/(E$2*($A20-$A19)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B19-C19)*(A20-A19)*PI()*(8*25.4)/1000
20	=C20+G20/(E$2*($A21-$A20)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B20-C20)*(A21-A20)*PI()*(8*25.4)/1000
21	=C21+G21/(E$2*($A22-$A21)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B21-C21)*(A22-A21)*PI()*(8*25.4)/1000
22	=C22+G22/(E$2*($A23-$A22)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B22-C22)*(A23-A22)*PI()*(8*25.4)/1000
23	=C23+G23/(E$2*($A24-$A23)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B23-C23)*(A24-A23)*PI()*(8*25.4)/1000
24	=C24+G24/(E$2*($A25-$A24)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B24-C24)*(A25-A24)*PI()*(8*25.4)/1000
25	=C25+G25/(E$2*($A26-$A25)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B25-C25)*(A26-A25)*PI()*(8*25.4)/1000
26	=C26+G26/(E$2*($A27-$A26)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B26-C26)*(A27-A26)*PI()*(8*25.4)/1000
27	=C27+G27/(E$2*($A28-$A27)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B27-C27)*(A28-A27)*PI()*(8*25.4)/1000
28	=C28+G28/(E$2*($A29-$A28)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B28-C28)*(A29-A28)*PI()*(8*25.4)/1000
29	=C29+G29/(E$2*($A30-$A29)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B29-C29)*(A30-A29)*PI()*(8*25.4)/1000
30	=C30+G30/(E$2*($A31-$A30)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B30-C30)*(A31-A30)*PI()*(8*25.4)/1000
31	=C31+G31/(E$2*($A32-$A31)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B31-C31)*(A32-A31)*PI()*(8*25.4)/1000
32	=C32+G32/(E$2*($A33-$A32)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B32-C32)*(A33-A32)*PI()*(8*25.4)/1000
33	=C33+G33/(E$2*($A34-$A33)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B33-C33)*(A34-A33)*PI()*(8*25.4)/1000
34	=C34+G34/(E$2*($A35-$A34)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B34-C34)*(A35-A34)*PI()*(8*25.4)/1000
35	=C35+G35/(E$2*($A36-$A35)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B35-C35)*(A36-A35)*PI()*(8*25.4)/1000
36	=C36+G36/(E$2*($A37-$A36)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B36-C36)*(A37-A36)*PI()*(8*25.4)/1000
37	=C37+G37/(E$2*($A38-$A37)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B37-C37)*(A38-A37)*PI()*(8*25.4)/1000
38	=C38+G38/(E$2*($A39-$A38)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B38-C38)*(A39-A38)*PI()*(8*25.4)/1000
39	=C39+G39/(E$2*($A40-$A39)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B39-C39)*(A40-A39)*PI()*(8*25.4)/1000
40	=C40+G40/(E$2*($A41-$A40)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B40-C40)*(A41-A40)*PI()*(8*25.4)/1000
41	=C41+G41/(E$2*($A42-$A41)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B41-C41)*(A42-A41)*PI()*(8*25.4)/1000
42	=C42+G42/(E$2*($A43-$A42)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B42-C42)*(A43-A42)*PI()*(8*25.4)/1000
43	=C43+G43/(E$2*($A44-$A43)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B43-C43)*(A44-A43)*PI()*(8*25.4)/1000
44	=C44+G44/(E$2*($A45-$A44)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B44-C44)*(A45-A44)*PI()*(8*25.4)/1000
45	=C45+G45/(E$2*($A46-$A45)*PI()*(12*25.4)/1000)	=F$6	=$G$2*(B45-C45)*(A46-A45)*PI()*(8*25.4)/1000

APPENDIX 2

SAMPLE PRINTOUTS OF CHIMNEY MODEL

Air-Cooled Chimney Model

Height Above Base M	Flue Gas Temp C	Cooling air Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Cooling Flow L/s	Ui=6 5 Heat Loss Watts	Uo=4 5 Exterior Heat loss
0.00	150.00	21.00	21.00	113.54	21.00	110 00	5.00	53 53	0.00
0.10	149.41	29.95	21.00	115 65	25.48	110 00	5.00	49 57	3 86
0.20	148.87	37.83	21.00	117.49	29 41	110 00	5 00	46 08	7.25
0.30	148.37	44.69	21.00	119 07	32 85	110 00	5 00	43 02	10 21
0 40	147.90	50.62	21.00	120.41	35 81	110 00	5.00	40 37	12 76
0.50	147.46	55.70	21.00	121.53	38 35	110 00	5 00	38 07	14 95
0.60	147.05	60.03	21.00	122.46	40 51	110 00	5 00	36 11	16 82
0.70	146.66	63.68	21.00	123.21	42 34	110 00	5 00	34 43	18 39
0.80	146.28	66.75	21.00	123 81	43 88	110 00	5 00	33 00	19 72
0.90	145.93	69.32	21.00	124.28	45 16	110 00	5 00	31 79	20 82
1.00	145.58	71.46	21.00	124.63	46 23	110 00	5 00	30 76	21 74
1.10	145.25	73.22	21.00	124 89	47 11	110 00	5 00	29 89	22 50
1 20	144.92	74.68	21.00	125 07	47 84	110 00	5 00	29 15	23 13
1.30	144.61	75.87	21.00	125 18	48 43	110 00	5 00	28 52	23 64
1.40	144.30	76.84	21.00	125 24	48 92	110 00	5 00	27 99	24 06
1.50	144.00	77.62	21.00	125 24	49 31	110 00	5 00	27 54	24 40
1.60	143.70	78.25	21.00	125 20	49 62	110 00	5 00	27 16	24 67
1.70	143.41	78.74	21.00	125 14	49 87	110 00	5 00	26 83	24 88
1.80	143.12	79 13	21.00	125.04	50.07	110 00	5 00	26 55	25 05
1.90	142.84	79.44	21.00	124.92	50 22	110 00	5 00	26 31	25 18
2.00	142.55	79.66	21.00	124 78	50 33	110 00	5 00	26 10	25 28
2.10	142.27	79.83	21.00	124.62	50 41	110 00	5 00	25 91	25 35
2.20	141.99	79.94	21.00	124 46	50 47	110 00	5 00	25 75	25 40
2.30	141 72	80.01	21.00	124 28	50 50	110 00	5 00	25 61	25 43
2.40	141 44	80.05	21.00	124 09	50 52	110 00	5 00	25 48	25 44
2.50	141 17	80.05	21.00	123 90	50 53	110 00	5 00	25 36	25 45
2.60	140 90	80.04	21.00	123 70	50 52	110 00	5 00	25 25	25 44
2.70	140 63	80.00	21.00	123 49	50 50	110 00	5 00	25 16	25 42
2.80	140 36	79.95	21.00	123 29	50 47	110 00	5 00	25 07	25 40
2.90	140 09	79 88	21.00	123 07	50 44	110 00	5 00	24 98	25 37
3.00	139 82	79 80	21.00	122 86	50 40	110 00	5 00	24 91	25 34
3.10	139 56	79 71	21.00	122 65	50 36	110 00	5 00	24 83	25 30
3.20	139 29	79 62	21.00	122 43	50 31	110 00	5 00	24 76	25 26
3.30	139 03	79 52	21.00	122 21	50 26	110 00	5 00	24 69	25 22
3 40	138 77	79 42	21 00	121 99	50 21	110 00	5 00	24 63	25 17
3 50	138 50	79 31	21 00	121 77	50 15	110 00	5 00	24 56	25 12
3 60	138 24	79 19	21 00	121 56	50 10	110 00	5 00	24 50	25 08
3 70	137 98	79 08	21 00	121 34	50 04	110 00	5 00	24 44	25 03
3 80	137 72	78 96	21 00	121 12	49 98	110 00	5 00	24 38	24 98
3 90	137 46	78 84	21 00	120 90	49 92	110 00	5 00	24 32	24 92

Air-Cooled Chimney Model

Height Above Base M	Flue Gas Temp C	Cooling air Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Cooling Flow L/s	Ui=6 5 Heat Loss Watts	Uo=4 5 Exterior Heat loss
0 00	200 00	-40 00	25 00	132 17	-7 50	110 00	4 00	99 59	-28 01
0 10	198 78	-18 86	25 00	137 27	3 07	110 00	4 00	90 31	-18 90
0 20	197 68	0 87	25 00	142 06	12 94	110 00	4 00	81 66	-10 40
0 30	196 69	18 80	25 00	146 41	21 90	110 00	4 00	73 81	-2 67
0 40	195 79	34 67	25 00	150 26	29 83	110 00	4 00	66 86	4 17
0 50	194 98	48 38	25 00	153 55	36 69	110 00	4 00	60 83	10 08
0 60	194 24	59 98	25 00	156 30	42 49	110 00	4 00	55 71	15 07
0 70	193 57	69 60	25 00	158 54	47 30	110 00	4 00	51 44	19 22
0 80	192 95	77 45	25 00	160 31	51 23	110 00	4 00	47 93	22 60
0 90	192 37	83 76	25 00	161 68	54 38	110 00	4 00	45 07	25 32
1 00	191 83	88 77	25 00	162 71	56 89	110 00	4 00	42 76	27 48
1 10	191 32	92 70	25 00	163 45	58 85	110 00	4 00	40 92	29 17
1 20	190 83	95 76	25 00	163 96	60 38	110 00	4 00	39 45	30 49
1 30	190 35	98 11	25 00	164 28	61 55	110 00	4 00	38 28	31 50
1 40	189 89	99 89	25 00	164 46	62 45	110 00	4 00	37 34	32 27
1 50	189 45	101 24	25 00	164 52	63 12	110 00	4 00	36 60	32 85
1 60	189 01	102 24	25 00	164 49	63 62	110 00	4 00	36 01	33 28
1 70	188 58	102 96	25 00	164 38	63 98	110 00	4 00	35 53	33 59
1 80	188 16	103 48	25 00	164 23	64 24	110 00	4 00	35 14	33 82
1 90	187 74	103 83	25 00	164 02	64 42	110 00	4 00	34 82	33 97
2 00	187 32	104 06	25 00	163 79	64 53	110 00	4 00	34 55	34 07
2 10	186 91	104 19	25 00	163 53	64 59	110 00	4 00	34 32	34 12
2 20	186 50	104 24	25 00	163 25	64 62	110 00	4 00	34 13	34 15
2 30	186 10	104 24	25 00	162 96	64 62	110 00	4 00	33 97	34 14
2 40	185 69	104 19	25 00	162 66	64 60	110 00	4 00	33 82	34 12
2 50	185 29	104 11	25 00	162 35	64 55	110 00	4 00	33 69	34 09
2 60	184 89	104 00	25 00	162 03	64 50	110 00	4 00	33 57	34 04
2 70	184 50	103 87	25 00	161 71	64 44	110 00	4 00	33 45	33 99
2 80	184 10	103 73	25 00	161 39	64 37	110 00	4 00	33 35	33 93
2 90	183 71	103 58	25 00	161 06	64 29	110 00	4 00	33 25	33 86
3 00	183 31	103 41	25 00	160 73	64 21	110 00	4 00	33 15	33 79
3 10	182 92	103 24	25 00	160 40	64 12	110 00	4 00	33 06	33 72
3 20	182 53	103 07	25 00	160 08	64 03	110 00	4 00	32 97	33 64
3 30	182 14	102 89	25 00	159 75	63 95	110 00	4 00	32 89	33 56
3 40	181 76	102 71	25 00	159 42	63 85	110 00	4 00	32 80	33 48
3 50	181 37	102 53	25 00	159 09	63 76	110 00	4 00	32 72	33 41
3 60	180 99	102 34	25 00	158 76	63 67	110 00	4 00	32 63	33 33
3 70	180 60	102 16	25 00	158 43	63 58	110 00	4 00	32 55	33 25
3 80	180 22	101 97	25 00	158 11	63 49	110 00	4 00	32 47	33 17
3 90	179 84	101 79	25 00	157 78	63 39	110 00	4 00	32 39	33 09

Air-Cooled Chimney Model

Height Above Base M	Flue Gas Temp C	Cooling air Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Cooling Flow L/s	Ui=6 5 Heat Loss Watts	Uo=4 5 Exterior Heat loss
0.00	200.00	25.00	25.00	150 54	25 00	110.00	4.00	72 61	0 00
0.10	199.11	40.39	25.00	154.25	32 69	110 00	4.00	65.86	6 63
0.20	198.31	53.58	25.00	157.41	39.29	110.00	4.00	60 05	12 32
0.30	197 58	64.67	25.00	160.02	44 83	110.00	4 00	55 15	17 09
0.40	196.91	73.81	25.00	162.12	49.40	110 00	4.00	51 08	21 03
0.50	196.28	81.22	25.00	163.77	53 11	110.00	4.00	47.75	24 22
0.60	195.71	87.14	25.00	165.02	56 07	110 00	4 00	45.05	26 78
0.70	195.16	91.82	25.00	165 95	58.41	110.00	4.00	42 88	28 79
0.80	194.64	95.47	25.00	166.61	60.24	110 00	4 00	41.15	30.37
0.90	194.14	98.30	25.00	167.06	61 65	110.00	4.00	39.77	31 58
1.00	193.66	100.46	25.00	167.32	62.73	110.00	4.00	38.67	32.52
1.10	193.20	102.09	25.00	167.45	63.55	110.00	4.00	37.80	33.22
1.20	192.74	103.32	25.00	167.47	64.16	110.00	4 00	37.11	33.75
1.30	192.29	104.22	25.00	167.40	64 61	110.00	4.00	36.55	34.13
1.40	191.85	104.86	25.00	167.27	64.93	110 00	4.00	36.10	34.41
1.50	191.42	105.31	25.00	167.09	65.16	110.00	4.00	35.73	34.61
1.60	190.99	105.62	25.00	166.86	65.31	110 00	4.00	35 43	34.74
1.70	190.57	105.80	25.00	166.61	65.40	110.00	4.00	35.17	34.82
1.80	190.14	105.90	25.00	166.34	65.45	110.00	4.00	34.96	34.86
1.90	189.73	105.92	25.00	166.04	65.46	110.00	4.00	34.77	34.87
2.00	189.31	105.90	25.00	165.74	65.45	110 00	4.00	34.61	34.86
2.10	188.90	105.83	25.00	165.42	65.42	110.00	4.00	34.47	34.83
2.20	188.48	105 73	25.00	165.10	65.37	110 00	4.00	34.34	34.79
2.30	188.07	105.61	25.00	164.77	65.31	110.00	4.00	34.22	34.74
2.40	187.67	105.47	25.00	164.44	65.24	110.00	4.00	34.11	34.68
2.50	187.26	105.32	25.00	164.10	65 16	110.00	4.00	34.00	34.61
2.60	186.86	105.16	25.00	163.77	65.08	110.00	4 00	33.90	34.54
2.70	186.45	104.98	25.00	163.43	64.99	110.00	4.00	33 80	34.46
2.80	186.05	104.81	25.00	163.09	64.90	110.00	4.00	33.71	34.39
2.90	185.65	104.62	25.00	162.75	64.81	110.00	4.00	33.62	34.31
3.00	185.25	104.44	25.00	162.41	64.72	110 00	4.00	33.53	34.23
3.10	184.85	104.25	25.00	162.08	64.63	110.00	4.00	33.45	34.15
3.20	184.46	104.06	25.00	161.74	64.53	110.00	4.00	33.36	34.07
3.30	184.06	103.87	25.00	161.40	64 44	110.00	4.00	33.27	33.99
3.40	183.67	103.68	25.00	161.07	64.34	110.00	4.00	33.19	33.90
3.50	183.28	103.49	25.00	160 73	64 25	110.00	4 00	33 11	33.82
3.60	182.89	103.30	25.00	160 40	64 15	110 00	4 00	33 02	33 74
3.70	182 50	103.11	25.00	160 06	64 05	110 00	4 00	32 94	33.66
3.80	182.11	102.92	25.00	159 73	63 96	110 00	4 00	32 86	33 57
3.90	181.72	102 73	25 00	159 40	63 86	110 00	4 00	32 78	33 49

Air-Cooled Chimney Model

Height Above Base M	Flue Gas Temp C	Cooling air Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Cooling Flow L/s	Ui=6 5 Heat Loss Watts	Uo=4 5 Exterior Heat loss
0.00	200.00	-15.00	25.00	139 24	5.00	110 00	4 00	89 21	-17 24
0.10	198.91	4.53	25.00	143 98	14.76	110 00	4 00	80 66	-8 82
0.20	197.92	22.18	25.00	148 26	23.59	110 00	4.00	72 92	-1 21
0.30	197.04	37.74	25.00	152 02	31 37	110 00	4 00	66 10	5 49
0.40	196.23	51.14	25.00	155 23	38 07	110.00	4 00	60 21	11 26
0.50	195.50	62.42	25.00	157 89	43.71	110 00	4 00	55 22	16 12
0.60	194.83	71.74	25.00	160 05	48.37	110.00	4 00	51 08	20 14
0.70	194.22	79.32	25.00	161 75	52 16	110 00	4 00	47 67	23 41
0.80	193.64	85.40	25.00	163 05	55 20	110 00	4 00	44 91	26 03
0.90	193.10	90.22	25.00	164 02	57 61	110 00	4 00	42 69	28 10
1.00	192.58	93.98	25.00	164 72	59 49	110 00	4 00	40 91	29.72
1.10	192.09	96.90	25.00	165 19	60 95	110 00	4 00	39 50	30 98
1.20	191.62	99.14	25.00	165.48	62 07	110 00	4 00	38 37	31 95
1.30	191.16	100.84	25.00	165.63	62 92	110 00	4 00	37 47	32.68
1.40	190.71	102.12	25.00	165 67	63 56	110 00	4 00	36 76	33 23
1.50	190.27	103.06	25.00	165.62	64.03	110 00	4.00	36 19	33.64
1.60	189.83	103.74	25.00	165.50	64 37	110.00	4 00	35.72	33 93
1.70	189.40	104.22	25.00	165.33	64 61	110.00	4 00	35 35	34 14
1.80	188.98	104.55	25.00	165.12	64.77	110 00	4.00	35.04	34.28
1.90	188.56	104.75	25.00	164.88	64.87	110.00	4.00	34.78	34.36
2.00	188.15	104.86	25.00	164 61	64 93	110.00	4.00	34 56	34 41
2.10	187.74	104.90	25.00	164.33	64.95	110 00	4 00	34 37	34 43
2.20	187.33	104.88	25.00	164.03	64.94	110 00	4 00	34 21	34.42
2.30	186.92	104.83	25.00	163.72	64.91	110.00	4 00	34 06	34 40
2.40	186.51	104.74	25.00	163.40	64.87	110.00	4 00	33 93	34.36
2.50	186.11	104.62	25.00	163.08	64.81	110.00	4.00	33 81	34.31
2.60	185.71	104.49	25.00	162.76	64.74	110.00	4.00	33 70	34 25
2.70	185.31	104.34	25.00	162.43	64.67	110.00	4.00	33 60	34 19
2.80	184.91	104.18	25.00	162.10	64.59	110.00	4.00	33 50	34 12
2.90	184.52	104.02	25.00	161.77	64.51	110.00	4.00	33.40	34 05
3.00	184.12	103.84	25.00	161.43	64.42	110.00	4 00	33 31	33.97
3.10	183.73	103.67	25.00	161.10	64.33	110.00	4 00	33 22	33.90
3.20	183.33	103.48	25.00	160.77	64.24	110 00	4.00	33 13	33.82
3.30	182.94	103.30	25.00	160.44	64.15	110.00	4.00	33 05	33.74
3.40	182.55	103.12	25.00	160.10	64.06	110.00	4 00	32 96	33.66
3.50	182.17	102.93	25.00	159.77	63 96	110 00	4 00	32 88	33 58
3.60	181.78	102.74	25.00	159 44	63 87	110 00	4 00	32 80	33 50
3 70	181.39	102.55	25.00	159.11	63 78	110 00	4 00	32 71	33 42
3.80	181.01	102.37	25.00	158.78	63 68	110 00	4 00	32 63	33 34
3 90	180.63	102.18	25.00	158 46	63 59	110 00	4 00	32 55	33 26

Air-Cooled Chimney Model

Height Above Base M	Flue Gas Temp C	Cooling air Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Cooling Flow L/s	Ui=6 5 Heat Loss Watts	Uo=4 5 Exterior Heat loss
0.00	200.00	-15.00	25.00	139.24	5.00	50.00	4.00	89.21	-17.24
0.10	197.60	4.53	25.00	143.04	14.76	50.00	4.00	80.11	-8.82
0.20	195.46	22.08	25.00	146.46	23.54	50.00	4.00	71.94	-1.26
0.30	193.54	37.44	25.00	149.42	31.22	50.00	4.00	64.77	5.36
0.40	191.82	50.55	25.00	151.90	37.78	50.00	4.00	58.62	11.01
0.50	190.27	61.50	25.00	153.88	43.25	50.00	4.00	53.43	15.73
0.60	188.86	70.47	25.00	155.40	47.74	50.00	4.00	49.13	19.59
0.70	187.57	77.68	25.00	156.52	51.34	50.00	4.00	45.60	22.70
0.80	186.38	83.39	25.00	157.27	54.20	50.00	4.00	42.73	25.16
0.90	185.26	87.84	25.00	157.73	56.42	50.00	4.00	40.42	27.08
1.00	184.21	91.27	25.00	157.94	58.13	50.00	4.00	38.56	28.55
1.10	183.20	93.86	25.00	157.95	59.43	50.00	4.00	37.07	29.67
1.20	182.24	95.79	25.00	157.81	60.40	50.00	4.00	35.87	30.50
1.30	181.31	97.20	25.00	157.54	61.10	50.00	4.00	34.90	31.11
1.40	180.41	98.20	25.00	157.18	61.60	50.00	4.00	34.11	31.54
1.50	179.53	98.88	25.00	156.74	61.94	50.00	4.00	33.47	31.83
1.60	178.67	99.31	25.00	156.24	62.15	50.00	4.00	32.93	32.02
1.70	177.82	99.55	25.00	155.70	62.27	50.00	4.00	32.48	32.12
1.80	176.99	99.64	25.00	155.13	62.32	50.00	4.00	32.09	32.16
1.90	176.17	99.62	25.00	154.54	62.31	50.00	4.00	31.76	32.16
2.00	175.36	99.52	25.00	153.92	62.26	50.00	4.00	31.47	32.11
2.10	174.55	99.35	25.00	153.30	62.17	50.00	4.00	31.21	32.04
2.20	173.76	99.13	25.00	152.67	62.06	50.00	4.00	30.97	31.94
2.30	172.97	98.87	25.00	152.03	61.94	50.00	4.00	30.75	31.83
2.40	172.19	98.58	25.00	151.39	61.79	50.00	4.00	30.54	31.71
2.50	171.42	98.28	25.00	150.75	61.64	50.00	4.00	30.35	31.58
2.60	170.65	97.95	25.00	150.11	61.48	50.00	4.00	30.17	31.44
2.70	169.89	97.62	25.00	149.47	61.31	50.00	4.00	29.99	31.29
2.80	169.14	97.28	25.00	148.83	61.14	50.00	4.00	29.82	31.14
2.90	168.39	96.93	25.00	148.19	60.96	50.00	4.00	29.65	30.99
3.00	167.64	96.57	25.00	147.56	60.79	50.00	4.00	29.49	30.84
3.10	166.90	96.22	25.00	146.93	60.61	50.00	4.00	29.33	30.69
3.20	166.17	95.86	25.00	146.30	60.43	50.00	4.00	29.17	30.53
3.30	165.44	95.50	25.00	145.67	60.25	50.00	4.00	29.02	30.38
3.40	164.72	95.15	25.00	145.05	60.07	50.00	4.00	28.87	30.23
3.50	164.00	94.79	25.00	144.44	59.90	50.00	4.00	28.72	30.07
3.60	163.28	94.44	25.00	143.83	59.72	50.00	4.00	28.57	29.92
3.70	162.57	94.08	25.00	143.22	59.54	50.00	4.00	28.42	29.77
3.80	161.87	93.73	25.00	142.61	59.37	50.00	4.00	28.27	29.62
3.90	161.17	93.38	25.00	142.01	59.19	50.00	4.00	28.13	29.47

Air-Cooled Chimney Model

Height Above Base M	Flue Gas Temp C°	Cooling air Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Cooling Flow L/s	Ui=6 5 Heat Loss Watts	Uo=4 5 Exterior Heat loss
0.00	200.00	-15.00	25.00	139 24	5 00	100 00	7 00	89 21	-17.24
0.10	198.80	-3 84	25.00	141 53	10 58	100 00	7 00	84 08	-12 43
0.20	197.67	6 71	25.00	143 71	15 86	100 00	7 00	79 24	-7 88
0.30	196.61	16.61	25.00	145 74	20 81	100 00	7 00	74 69	-3 61
0.40	195.61	25.83	25.00	147.63	25.41	100 00	7 00	70 45	0 36
0.50	194.67	34.34	25.00	149 36	29.67	100 00	7 00	66 53	4 02
0.60	193.79	42.14	25.00	150 93	33 57	100 00	7 00	62 92	7 39
0.70	192.95	49.25	25.00	152 34	37 13	100 00	7 00	59 63	10 45
0.80	192.16	55.69	25.00	153 60	40 35	100 00	7 00	56 63	13 23
0.90	191.41	61.49	25.00	154 70	43 24	100 00	7 00	53 91	15 72
1.00	190.70	66.68	25.00	155.65	45.84	100 00	7 00	51 46	17 96
1.10	190.02	71.30	25.00	156 47	48.15	100 00	7 00	49 26	19 95
1.20	189.38	75.40	25.00	157 17	50.20	100 00	7 00	47 29	21 72
1.30	188.75	79.02	25.00	157.74	52.01	100 00	7 00	45 53	23 28
1.40	188.16	82.21	25.00	158 21	53.60	100 00	7 00	43 96	24 65
1.50	187.58	84.99	25.00	158 59	55 00	100 00	7 00	42.57	25 85
1.60	187.02	87.43	25.00	158.87	56.21	100 00	7 00	41 33	26 90
1.70	186.48	89.54	25.00	159 08	57.27	100 00	7 00	40 23	27 81
1.80	185.95	91.37	25.00	159.22	58.18	100 00	7 00	39 25	28 60
1.90	185.44	92.94	25.00	159.30	58 97	100 00	7 00	38 38	29 28
2.00	184.94	94.30	25.00	159 32	59 65	100 00	7 00	37 61	29 86
2.10	184.45	95.45	25.00	159.30	60.23	100 00	7 00	36 93	30 36
2.20	183.97	96.44	25.00	159.23	60.72	100 00	7 00	36 32	30 78
2.30	183.50	97.27	25.00	159 13	61.13	100 00	7 00	35.78	31 14
2.40	183.03	97.97	25.00	158 99	61.48	100 00	7 00	35 30	31 44
2.50	182.58	98.55	25.00	158.83	61.77	100 00	7 00	34 87	31 69
2.60	182.13	99.03	25.00	158.64	62.01	100 00	7 00	34 48	31 90
2.70	181.68	99.42	25.00	158 43	62.21	100 00	7 00	34 13	32 07
2.80	181.24	99.73	25.00	158.20	62.37	100 00	7 00	33 82	32 20
2.90	180.80	99.98	25.00	157.96	62 49	100 00	7 00	33 54	32 31
3.00	180.37	100.16	25.00	157 70	62 58	100 00	7 00	33 28	32 39
3.10	179.94	100.30	25.00	157 43	62 65	100 00	7 00	33 05	32 45
3.20	179.51	100.39	25.00	157 15	62 69	100 00	7 00	32 83	32 49
3.30	179.09	100.44	25.00	156.86	62.72	100 00	7 00	32 63	32 51
3.40	178.67	100.46	25.00	156 57	62 73	100 00	7 00	32 45	32 52
3.50	178.25	100.45	25.00	156 27	62 73	100 00	7 00	32 28	32 51
3.60	177.84	100.42	25.00	155 96	62 71	100 00	7 00	32 13	32 50
3.70	177.43	100.36	25.00	155 65	62 68	100 00	7 00	31 98	32 47
3 80	177.02	100 29	25.00	155 33	62 64	100 00	7 00	31 84	32 44
3 90	176.61	100 19	25.00	155 01	62 60	100 00	7 00	31 71	32 40

Air-Cooled Chimney Model

Height Above Base M	Flue Gas Temp C	Cooling air Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Cooling Flow L/s	Ui=6.5 Heat Loss Watts	Uo=4.5 Exterior Heat loss
0.00	400.00	25.00	25.00	294.02	25.00	100.00	7.00	155.60	0.00
0.10	397.02	43.84	25.00	297.21	34.42	100.00	7.00	146.55	8.12
0.20	394.23	61.66	25.00	300.24	43.33	100.00	7.00	138.00	15.80
0.30	391.61	78.28	25.00	303.06	51.64	100.00	7.00	130.01	22.96
0.40	389.15	93.56	25.00	305.61	59.28	100.00	7.00	122.65	29.54
0.50	386.84	107.42	25.00	307.88	66.21	100.00	7.00	115.94	35.52
0.60	384.67	119.86	25.00	309.83	72.43	100.00	7.00	109.88	40.87
0.70	382.61	130.87	25.00	311.47	77.94	100.00	7.00	104.46	45.62
0.80	380.66	140.53	25.00	312.80	82.76	100.00	7.00	99.64	49.78
0.90	378.81	148.90	25.00	313.84	86.95	100.00	7.00	95.40	53.39
1.00	377.04	156.10	25.00	314.60	90.55	100.00	7.00	91.68	56.49
1.10	375.35	162.24	25.00	315.12	93.62	100.00	7.00	88.43	59.14
1.20	373.72	167.42	25.00	315.42	96.21	100.00	7.00	85.60	61.37
1.30	372.14	171.76	25.00	315.51	98.38	100.00	7.00	83.15	63.24
1.40	370.62	175.35	25.00	315.43	100.18	100.00	7.00	81.02	64.79
1.50	369.13	178.31	25.00	315.21	101.66	100.00	7.00	79.18	66.06
1.60	367.69	180.72	25.00	314.85	102.86	100.00	7.00	77.58	67.10
1.70	366.27	182.65	25.00	314.38	103.82	100.00	7.00	76.19	67.93
1.80	364.89	184.18	25.00	313.82	104.59	100.00	7.00	74.98	68.59
1.90	363.53	185.37	25.00	313.18	105.18	100.00	7.00	73.93	69.10
2.00	362.19	186.27	25.00	312.47	105.63	100.00	7.00	73.00	69.49
2.10	360.87	186.92	25.00	311.71	105.96	100.00	7.00	72.18	69.77
2.20	359.57	187.37	25.00	310.90	106.18	100.00	7.00	71.45	69.97
2.30	358.28	187.65	25.00	310.06	106.32	100.00	7.00	70.80	70.09
2.40	357.01	187.78	25.00	309.19	106.39	100.00	7.00	70.22	70.14
2.50	355.75	187.80	25.00	308.29	106.40	100.00	7.00	69.69	70.15
2.60	354.51	187.71	25.00	307.37	106.36	100.00	7.00	69.21	70.11
2.70	353.27	187.54	25.00	306.44	106.27	100.00	7.00	68.77	70.04
2.80	352.05	187.30	25.00	305.49	106.15	100.00	7.00	68.36	69.94
2.90	350.83	187.01	25.00	304.54	106.00	100.00	7.00	67.98	69.81
3.00	349.63	186.67	25.00	303.57	105.83	100.00	7.00	67.62	69.66
3.10	348.43	186.29	25.00	302.61	105.64	100.00	7.00	67.28	69.50
3.20	347.24	185.87	25.00	301.64	105.44	100.00	7.00	66.96	69.32
3.30	346.06	185.43	25.00	300.66	105.22	100.00	7.00	66.65	69.13
3.40	344.89	184.97	25.00	299.69	104.98	100.00	7.00	66.36	68.93
3.50	343.72	184.49	25.00	298.72	104.75	100.00	7.00	66.07	68.72
3.60	342.56	184.00	25.00	297.75	104.50	100.00	7.00	65.79	68.51
3.70	341.41	183.49	25.00	296.78	104.25	100.00	7.00	65.53	68.29
3.80	340.26	182.98	25.00	295.81	103.99	100.00	7.00	65.26	68.07
3.90	339.13	182.46	25.00	294.85	103.73	100.00	7.00	65.01	67.85

Air-Cooled Chimney Model

Height Above Base M	Flue Gas Temp C	Cooling air Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Cooling Flow L/s	Ui=6 5 Heat Loss Watts	Uo=4 5 Exterior Heat loss
0.00	400.00	25.00	25.00	294.02	25.00	120.00	5.00	155 60	0.00
0.10	397.52	51.38	25.00	299.70	38 19	120 00	5 00	143 63	11 37
0.20	395.24	75.78	25.00	304.95	50.39	120 00	5 00	132 55	21.88
0.30	393.14	97.74	25 00	309.65	61 37	120 00	5 00	122.57	31 34
0.40	391.20	116.98	25.00	313.70	70 99	120 00	5 00	113 79	39 63
0.50	389.41	133.43	25.00	317 07	79 21	120 00	5 00	106 22	46 72
0.60	387.74	147.18	25.00	319 76	86 09	120 00	5 00	99 82	52 65
0.70	386.18	158.46	25.00	321 82	91.73	120 00	5.00	94.49	57.51
0.80	384.70	167.53	25.00	323.33	96.27	120.00	5 00	90 11	61 42
0.90	383.30	174.72	25.00	324.35	99.86	120.00	5 00	86.55	64 52
1.00	381.95	180.33	25.00	324.97	102.67	120.00	5 00	83.66	66.93
1.10	380.65	184.65	25.00	325.26	104.82	120.00	5 00	81 33	68.79
1.20	379.39	187.91	25.00	325.28	106.46	120 00	5 00	79.45	70.20
1.30	378.16	190.34	25.00	325.08	107.67	120 00	5 00	77 94	71.24
1.40	376.96	192.10	25.00	324.72	108.55	120 00	5 00	76.71	72.00
1.50	375.78	193.35	25.00	324.22	109.17	120 00	5.00	75.70	72.54
1.60	374.62	194.18	25.00	323.62	109.59	120 00	5.00	74.87	72.90
1.70	373.47	194.71	25.00	322.95	109.85	120 00	5.00	74.17	73.13
1.80	372.33	194.99	25.00	322.21	109 99	120.00	5.00	73.59	73.25
1.90	371.20	195.08	25.00	321.43	110.04	120 00	5 00	73 08	73.29
2.00	370.09	195.02	25.00	320.61	110.01	120.00	5 00	72 64	73.26
2.10	368.98	194.86	25.00	319.77	109.93	120.00	5.00	72.25	73.19
2.20	367.88	194.61	25.00	318.91	109.80	120.00	5 00	71.90	73.08
2.30	366.79	194.29	25.00	318.04	109.65	120 00	5.00	71.58	72.95
2.40	365.70	193.93	25.00	317.16	109.46	120.00	5 00	71.28	72.79
2.50	364.63	193.53	25.00	316.27	109.26	120.00	5.00	71.00	72.62
2.60	363.55	193.10	25.00	315.38	109.05	120.00	5.00	70.73	72.43
2.70	362.49	192.64	25.00	314.49	108 82	120.00	5.00	70 47	72.24
2.80	361.42	192.18	25.00	313.59	108.59	120.00	5.00	70.23	72.04
2.90	360.37	191.70	25.00	312.70	108.35	120 00	5.00	69.99	71.83
3.00	359.32	191.21	25.00	311.81	108 11	120 00	5.00	69.75	71.62
3.10	358.27	190.72	25.00	310.92	107.86	120.00	5.00	69.53	71 41
3.20	357.23	190.22	25.00	310.03	107.61	120 00	5.00	69 30	71.19
3.30	356.20	189.72	25.00	309.15	107.36	120.00	5.00	69.08	70.98
3.40	355.17	189.22	25.00	308.27	107 11	120 00	5.00	68.86	70.76
3.50	354.14	188.72	25.00	307 39	106 86	120 00	5 00	68 64	70 55
3.60	353.12	188.22	25.00	306.52	106 61	120 00	5.00	68 42	70.33
3.70	352.11	187.72	25 00	305.65	106 36	120 00	5 00	68 21	70 12
3 80	351 10	187 22	25 00	304 78	106 11	120 00	5 00	68 00	69 90
3 90	350.09	186.72	25 00	303 92	105 86	120 00	5 00	67 79	69 69

Type A Chimney Model

Height Above Base M	Flue Gas Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	U1=3 Heat Loss Watts
0.00	245.00	25.00	216.30	69.00	150.00	42.13
0.10	244.59	25.00	215.94	68.92	150.00	42.05
0.20	244.17	25.00	215.59	68.83	150.00	41.97
0.30	243.76	25.00	215.23	68.75	150.00	41.90
0.40	243.35	25.00	214.87	68.67	150.00	41.82
0.50	242.94	25.00	214.51	68.59	150.00	41.74
0.60	242.53	25.00	214.16	68.51	150.00	41.66
0.70	242.13	25.00	213.81	68.43	150.00	41.58
0.80	241.72	25.00	213.45	68.34	150.00	41.50
0.90	241.32	25.00	213.10	68.26	150.00	41.43
1.00	240.91	25.00	212.75	68.18	150.00	41.35
1.10	240.51	25.00	212.40	68.10	150.00	41.27
1.20	240.11	25.00	212.05	68.02	150.00	41.20
1.30	239.71	25.00	211.70	67.94	150.00	41.12
1.40	239.31	25.00	211.35	67.86	150.00	41.04
1.50	238.91	25.00	211.01	67.78	150.00	40.97
1.60	238.51	25.00	210.66	67.70	150.00	40.89
1.70	238.11	25.00	210.32	67.62	150.00	40.81
1.80	237.72	25.00	209.97	67.54	150.00	40.74
1.90	237.32	25.00	209.63	67.46	150.00	40.66
2.00	236.93	25.00	209.29	67.39	150.00	40.59
2.10	236.54	25.00	208.95	67.31	150.00	40.51
2.20	236.15	25.00	208.61	67.23	150.00	40.44
2.30	235.76	25.00	208.27	67.15	150.00	40.36
2.40	235.37	25.00	207.93	67.07	150.00	40.29
2.50	234.98	25.00	207.59	67.00	150.00	40.21
2.60	234.59	25.00	207.25	66.92	150.00	40.14
2.70	234.20	25.00	206.92	66.84	150.00	40.06
2.80	233.82	25.00	206.58	66.76	150.00	39.99
2.90	233.43	25.00	206.25	66.69	150.00	39.92
3.00	233.05	25.00	205.91	66.61	150.00	39.84
3.10	232.67	25.00	205.58	66.53	150.00	39.77
3.20	232.29	25.00	205.25	66.46	150.00	39.70
3.30	231.91	25.00	204.92	66.38	150.00	39.63
3.40	231.53	25.00	204.59	66.31	150.00	39.55
3.50	231.15	25.00	204.26	66.23	150.00	39.48
3.60	230.77	25.00	203.93	66.15	150.00	39.41
3.70	230.40	25.00	203.60	66.08	150.00	39.34
3.80	230.02	25.00	203.28	66.00	150.00	39.26
3.90	229.65	25.00	202.95	65.93	150.00	39.19

Type A Chimney Model

Height Above Base M	Flue Gas Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Ui=4 Heat Loss Watts
0.00	245.00	25.00	206.74	83.67	150.00	56.18
0.10	244.45	25.00	206.28	83.52	150.00	56.04
0.20	243.90	25.00	205.83	83.37	150.00	55.90
0.30	243.35	25.00	205.38	83.23	150.00	55.76
0.40	242.80	25.00	204.93	83.08	150.00	55.62
0.50	242.26	25.00	204.48	82.94	150.00	55.48
0.60	241.72	25.00	204.03	82.79	150.00	55.34
0.70	241.18	25.00	203.58	82.65	150.00	55.20
0.80	240.64	25.00	203.14	82.50	150.00	55.06
0.90	240.10	25.00	202.69	82.36	150.00	54.93
1.00	239.57	25.00	202.25	82.22	150.00	54.79
1.10	239.04	25.00	201.81	82.08	150.00	54.65
1.20	238.51	25.00	201.38	81.94	150.00	54.52
1.30	237.98	25.00	200.94	81.79	150.00	54.38
1.40	237.45	25.00	200.50	81.65	150.00	54.25
1.50	236.93	25.00	200.07	81.51	150.00	54.12
1.60	236.40	25.00	199.64	81.37	150.00	53.98
1.70	235.88	25.00	199.21	81.24	150.00	53.85
1.80	235.36	25.00	198.78	81.10	150.00	53.72
1.90	234.84	25.00	198.35	80.96	150.00	53.58
2.00	234.33	25.00	197.92	80.82	150.00	53.45
2.10	233.81	25.00	197.50	80.68	150.00	53.32
2.20	233.30	25.00	197.08	80.55	150.00	53.19
2.30	232.79	25.00	196.65	80.41	150.00	53.06
2.40	232.28	25.00	196.23	80.28	150.00	52.93
2.50	231.78	25.00	195.81	80.14	150.00	52.80
2.60	231.27	25.00	195.40	80.01	150.00	52.67
2.70	230.77	25.00	194.98	79.87	150.00	52.54
2.80	230.26	25.00	194.57	79.74	150.00	52.41
2.90	229.76	25.00	194.15	79.60	150.00	52.29
3.00	229.27	25.00	193.74	79.47	150.00	52.16
3.10	228.77	25.00	193.33	79.34	150.00	52.03
3.20	228.27	25.00	192.92	79.21	150.00	51.91
3.30	227.78	25.00	192.51	79.07	150.00	51.78
3.40	227.29	25.00	192.11	78.94	150.00	51.65
3.50	226.80	25.00	191.70	78.81	150.00	51.53
3.60	226.31	25.00	191.30	78.68	150.00	51.40
3.70	225.82	25.00	190.90	78.55	150.00	51.28
3.80	225.34	25.00	190.50	78.42	150.00	51.16
3.90	224.86	25.00	190.10	78.29	150.00	51.03

Type A Chimney Model

Height Above Base M	Flue Gas Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	Ui=4 Heat Loss Watts
0.00	300.00	25.00	252.17	98.33	150.00	70.22
0.10	299.24	25.00	251.54	98.13	150.00	70.03
0.20	298.48	25.00	250.92	97.93	150.00	69.83
0.30	297.72	25.00	250.29	97.73	150.00	69.64
0.40	296.97	25.00	249.67	97.52	150.00	69.45
0.50	296.22	25.00	249.05	97.32	150.00	69.25
0.60	295.47	25.00	248.43	97.13	150.00	69.06
0.70	294.72	25.00	247.82	96.93	150.00	68.87
0.80	293.98	25.00	247.20	96.73	150.00	68.68
0.90	293.24	25.00	246.59	96.53	150.00	68.50
1.00	292.51	25.00	245.99	96.34	150.00	68.31
1.10	291.78	25.00	245.38	96.14	150.00	68.12
1.20	291.05	25.00	244.78	95.95	150.00	67.93
1.30	290.32	25.00	244.18	95.75	150.00	67.75
1.40	289.60	25.00	243.58	95.56	150.00	67.56
1.50	288.88	25.00	242.98	95.37	150.00	67.38
1.60	288.16	25.00	242.39	95.18	150.00	67.20
1.70	287.44	25.00	241.80	94.98	150.00	67.01
1.80	286.73	25.00	241.21	94.80	150.00	66.83
1.90	286.02	25.00	240.63	94.61	150.00	66.65
2.00	285.32	25.00	240.04	94.42	150.00	66.47
2.10	284.61	25.00	239.46	94.23	150.00	66.29
2.20	283.91	25.00	238.88	94.04	150.00	66.11
2.30	283.21	25.00	238.31	93.86	150.00	65.93
2.40	282.52	25.00	237.73	93.67	150.00	65.76
2.50	281.83	25.00	237.16	93.49	150.00	65.58
2.60	281.14	25.00	236.59	93.30	150.00	65.40
2.70	280.45	25.00	236.02	93.12	150.00	65.23
2.80	279.76	25.00	235.46	92.94	150.00	65.05
2.90	279.08	25.00	234.89	92.76	150.00	64.88
3.00	278.40	25.00	234.33	92.57	150.00	64.71
3.10	277.73	25.00	233.77	92.39	150.00	64.53
3.20	277.05	25.00	233.22	92.21	150.00	64.36
3.30	276.38	25.00	232.66	92.03	150.00	64.19
3.40	275.71	25.00	232.11	91.86	150.00	64.02
3.50	275.05	25.00	231.56	91.68	150.00	63.85
3.60	274.38	25.00	231.01	91.50	150.00	63.68
3.70	273.72	25.00	230.47	91.33	150.00	63.51
3.80	273.06	25.00	229.92	91.15	150.00	63.34
3.90	272.41	25.00	229.38	90.98	150.00	63.18

650 Chimney Model

Height Above Base M	Flue Gas Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	2 70 Heat Loss Watts
0.00	232.00	25.00	207.70	56.05	100.00	35.68
0.10	231.49	25.00	207.25	55.97	100.00	35.59
0.20	230.98	25.00	206.80	55.90	100.00	35.50
0.30	230.47	25.00	206.35	55.82	100.00	35.41
0.40	229.96	25.00	205.90	55.74	100.00	35.33
0.50	229.46	25.00	205.45	55.67	100.00	35.24
0.60	228.95	25.00	205.01	55.59	100.00	35.15
0.70	228.45	25.00	204.57	55.52	100.00	35.07
0.80	227.95	25.00	204.13	55.44	100.00	34.98
0.90	227.45	25.00	203.69	55.37	100.00	34.89
1.00	226.95	25.00	203.25	55.29	100.00	34.81
1.10	226.46	25.00	202.81	55.22	100.00	34.72
1.20	225.97	25.00	202.37	55.15	100.00	34.64
1.30	225.48	25.00	201.94	55.07	100.00	34.55
1.40	224.99	25.00	201.51	55.00	100.00	34.47
1.50	224.50	25.00	201.08	54.92	100.00	34.39
1.60	224.01	25.00	200.65	54.85	100.00	34.30
1.70	223.53	25.00	200.22	54.78	100.00	34.22
1.80	223.04	25.00	199.79	54.71	100.00	34.13
1.90	222.56	25.00	199.37	54.63	100.00	34.05
2.00	222.08	25.00	198.95	54.56	100.00	33.97
2.10	221.60	25.00	198.52	54.49	100.00	33.89
2.20	221.13	25.00	198.10	54.42	100.00	33.80
2.30	220.65	25.00	197.68	54.35	100.00	33.72
2.40	220.18	25.00	197.27	54.28	100.00	33.64
2.50	219.71	25.00	196.85	54.21	100.00	33.56
2.60	219.24	25.00	196.43	54.14	100.00	33.48
2.70	218.77	25.00	196.02	54.06	100.00	33.40
2.80	218.30	25.00	195.61	53.99	100.00	33.32
2.90	217.83	25.00	195.20	53.93	100.00	33.24
3.00	217.37	25.00	194.79	53.86	100.00	33.16
3.10	216.91	25.00	194.38	53.79	100.00	33.08
3.20	216.45	25.00	193.97	53.72	100.00	33.00
3.30	215.99	25.00	193.57	53.65	100.00	32.92
3.40	215.53	25.00	193.16	53.58	100.00	32.84
3.50	215.07	25.00	192.76	53.51	100.00	32.76
3.60	214.62	25.00	192.36	53.44	100.00	32.68
3.70	214.17	25.00	191.96	53.37	100.00	32.60
3.80	213.71	25.00	191.56	53.31	100.00	32.53
3.90	213.26	25.00	191.16	53.24	100.00	32.45

650 Chimney Model

Height Above Base M	Flue Gas Temp C	Outdoor air Temp C	Flue Liner Temp C	Outside Surf Temp C	Flue Flow L/s	2.70 Heat Loss Watts
0.00	360.00	0.00	317.74	54.00	100.00	62.05
0.10	358.88	0.00	316.75	53.83	100.00	61.86
0.20	357.77	0.00	315.77	53.67	100.00	61.67
0.30	356.66	0.00	314.80	53.50	100.00	61.47
0.40	355.56	0.00	313.82	53.33	100.00	61.29
0.50	354.47	0.00	312.86	53.17	100.00	61.10
0.60	353.38	0.00	311.89	53.01	100.00	60.91
0.70	352.29	0.00	310.94	52.84	100.00	60.72
0.80	351.21	0.00	309.98	52.68	100.00	60.54
0.90	350.14	0.00	309.04	52.52	100.00	60.35
1.00	349.07	0.00	308.09	52.36	100.00	60.17
1.10	348.00	0.00	307.15	52.20	100.00	59.98
1.20	346.94	0.00	306.22	52.04	100.00	59.80
1.30	345.89	0.00	305.29	51.88	100.00	59.62
1.40	344.84	0.00	304.36	51.73	100.00	59.44
1.50	343.80	0.00	303.44	51.57	100.00	59.26
1.60	342.76	0.00	302.52	51.41	100.00	59.08
1.70	341.72	0.00	301.61	51.26	100.00	58.90
1.80	340.69	0.00	300.70	51.10	100.00	58.72
1.90	339.67	0.00	299.79	50.95	100.00	58.55
2.00	338.65	0.00	298.89	50.80	100.00	58.37
2.10	337.63	0.00	298.00	50.64	100.00	58.19
2.20	336.62	0.00	297.11	50.49	100.00	58.02
2.30	335.62	0.00	296.22	50.34	100.00	57.85
2.40	334.61	0.00	295.33	50.19	100.00	57.67
2.50	333.62	0.00	294.45	50.04	100.00	57.50
2.60	332.63	0.00	293.58	49.89	100.00	57.33
2.70	331.64	0.00	292.71	49.75	100.00	57.16
2.80	330.65	0.00	291.84	49.60	100.00	56.99
2.90	329.68	0.00	290.98	49.45	100.00	56.82
3.00	328.70	0.00	290.12	49.31	100.00	56.66
3.10	327.73	0.00	289.26	49.16	100.00	56.49
3.20	326.77	0.00	288.41	49.02	100.00	56.32
3.30	325.81	0.00	287.56	48.87	100.00	56.16
3.40	324.85	0.00	286.72	48.73	100.00	55.99
3.50	323.90	0.00	285.88	48.58	100.00	55.83
3.60	322.95	0.00	285.04	48.44	100.00	55.66
3.70	322.01	0.00	284.21	48.30	100.00	55.50
3.80	321.07	0.00	283.38	48.16	100.00	55.34
3.90	320.13	0.00	282.55	48.02	100.00	55.18